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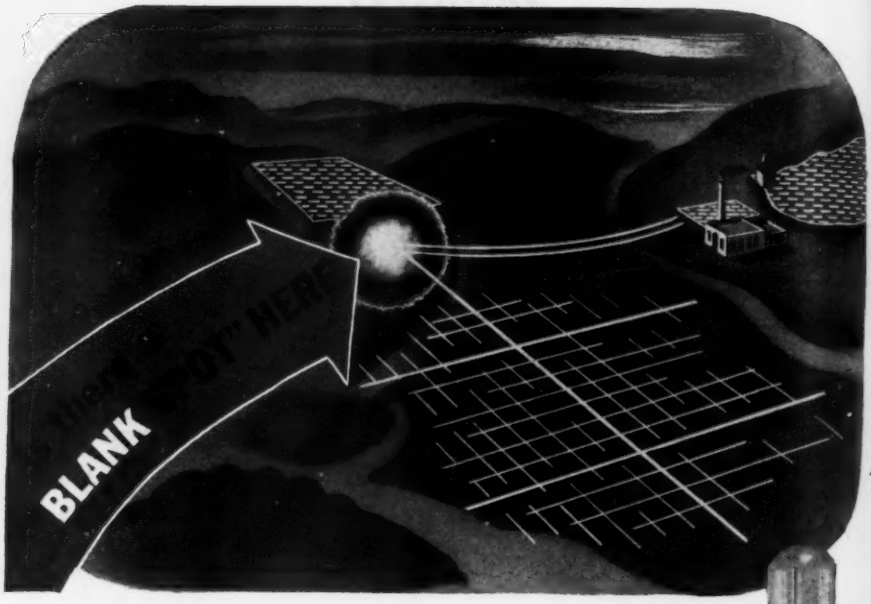

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Vol. 36 September 1944 No. 9

Wisconsin's Concept of Water Utility Regulation

By W. F. Whitney

THE policy of regulating private economic undertakings through governmental agencies is as old as "common law." Common law reflects public opinion, which in turn influences the ideals of the period. And public opinion, in the last analysis, has always insisted that government protect against those forces which threaten life—or the means of living.

During the Middle Ages, the policy of regulating all economic undertakings was quite general but in modern times the policy has been somewhat reversed. In any event, competition should largely regulate prices and service in modern business, except those, such as public utilities, which are monopolistic in their nature. In the latter cases, public welfare demands that the government shall step in and furnish whatever protection may be needed, which protection must be adjusted to the nature of the service rendered and to the all-around conditions under which it operates. The power thus vested in the state, under our form of government, is the power to regulate. This regulation may take the form of specific laws only, or it may take the form of laws administered by a state commission.

The Wisconsin Commission was organized in 1874 as the Wisconsin Railroad Commission. In 1907 this railroad commission was given jurisdiction over utilities other than railroads. The same year, 1907, the Public Service Commission of New York was established. (Incidentally, the Wisconsin and New York Commissions are the two oldest in the United States having jurisdiction over utilities other than railroads.) The Wisconsin and New York Commissions have served throughout the United States as models for other states. The Wisconsin Railroad Commission continued to operate until 1931, at which time the name was changed to Public Service Commission of Wisconsin, and also at which time

A paper presented on June 14, 1944, at the Milwaukee Conference by W. F. Whitney, Commissioner, Public Service Commission, State of Wisconsin, Madison, Wis.

the rights and duties were further enlarged and more specifically defined by the legislature.

The Wisconsin over-all concept of state regulation is to see that the public is given (1) adequate service (2) at a reasonable charge (3) without unjust discrimination and (4) without prejudice. One of our chief concepts has always been, and is now, that municipal utilities should be subject to substantially the same regulation as those privately owned. This concept differs from that of many other states where municipal utilities are not subject to regulation.

In Wisconsin it was recognized in the early periods of utility regulation that intelligent supervision of municipal water utilities could be effective only when based on accurate information and when administered without prejudice, with a high regard for justice and equity. When the commission was first established, the legislature apparently had in mind that an independent tribunal, free from local influence and assisted by a corps of highly trained personnel, would be better qualified than any city council to regulate municipal water systems. The legislature believed that (1) central control makes for economy; (2) the cost of a permanent staff of local experts would be prohibitive to most municipalities; (3) the commission could and should furnish water utilities with advice, but not with extended professional services in engineering and accounting; (4) a uniform system of accounts should be established for standardization and for comparative purposes.

The Wisconsin Statute (66.06(11)(c)) provides that the income of a municipal water utility shall first be used to meet all of the general operation and maintenance costs and, in addition, such items as depreciation, local and school tax equivalents, interest and sinking-fund requirements. Any income in excess of the sum of all of these requirements may be paid into the city's general fund. This particular section of the statute permits the managers of municipal utilities to operate without fear that the utilities' treasuries will be unduly depleted by paying for other costs of local government. A special word about the local and school tax equivalents, just mentioned, as a proper allowance in operating expenses: These tax equivalents are considered as an operating expense to be recovered through water rates for service, and the commission strongly encourages the actual payment in cash of these tax equivalents to the general fund. While it is true that municipal utilities are exempt from a number of taxes, such as state and federal income taxes and state ad valorem taxes, yet it is proper that the utility should pay its share of the local and school taxes into the city's treasury, before the calculation of any amount of income to be available to the general fund of a municipality.

By way of illustrating Wisconsin's method of regulation of the earnings of a public water utility, let us assume that the utility has a net property value of $100,000. The commission permits the utility to charge rates sufficient to cover all the general operation and maintenance expenses, including a definite amount for depreciation of the property, for local and school taxes, and for a reasonable percentage return. If, for instance, the local and school tax is 2 per cent, the commission will allow $2,000 as a part of operating expense; if 5 per cent is a reasonable rate of return, it will allow $5,000. The commission will also allow for depreciation

and for all other proper operation and maintenance expenses. The $2,000 tax money would be paid into the city's general fund as tax equivalents paid by the water utility to the city; likewise the $5,000 of fair return would be paid into the city's general fund, provided there were no prior demands on it for retirement of debt of the water utility or for necessary additions to its property. In any event, this $5,000 or 5 per cent return is a part of the utility's earned surplus and either is used for debt retirement, for property additions or is paid to the city in cash. If the water utility earned excessive returns over this $5,000, such excessive returns would likewise be available for the items just enumerated and might also inure to the benefit of the city. However, with proper regulation by the commission, the water rates charged to consumers should be kept at a level where such excessive returns would seldom be encountered. Water utilities should not be allowed to charge a rate that allows the utility, year in and year out, to have excessive surplus funds to turn into the city's general fund.

The Wisconsin Commission has always treated a water utility as one entity and a city as an entirely different entity. It has consistently held that records of all transactions between a municipal utility and the city itself should be separately set up and maintained. These transactions include such items as administrative or legal services rendered by the municipalities to the utility, or water furnished by the utility for fire protection and other general municipal uses. Care should be taken that all entries and net results be kept acurately, precisely, and in a manner to keep the public fully and fairly informed. If a municipally-owned water utility is to function on a sound economic basis, this separate water fund must be maintained so that checks for services can be passed from the utility to the city, and vice versa. The commission has insisted on this separate cash account for the municipal utility, not with the idea of depriving the municipality of any surplus earnings, but to insure that the water utility, as a proprietary undertaking, shall be operated on a plain, common-sense business basis.

Much confusion often exists as to just what monies should be treated as water utility funds and what ones as city funds. The commission receives many inquiries along this line. A list of some of the items involved follows. All cash coming into the city treasurer's hands from the following sources should be definitely allocated to the water utility:

1. Water customers' accounts receivable.
2. Collection of accounts covering piping and material sold to customers for laying services, etc.
3. Receipts from servicing customers' installations, thawing frozen services, connecting and disconnecting services, etc.
4. Receipts from the sale of junked and salvaged utility equipment.
5. Assessments levied for laying mains.
6. Receipts from any general obligation outstanding bonds that have been issued specifically for water utility purposes.
7. Receipts for cash that may have been transferred from the general fund as a temporary loan to cover heavy construction expenditures.
8. Receipts from contributions in aid of construction and other special assessments.

9. Receipts from customers' deposits.

10. Any receipts from refunds for overpayment, for cash discounts, or for adjustment of claims.

11. Interdepartmental transfers.

12. Rents which the utility receives from others for use of water operating property.

13. Income from utility plant leased to others.

14. Interest received on securities owned by the water utility.

On the other hand, the water utility should issue its own checks, against the water works cash account, for disbursements as follows:

1. Water utility payrolls.

2. For city employees performing any specific work for the utility.

3. For invoices covering materials purchased.

4. For invoices covering repair and maintenance charges.

5. For power purchased from private utilities.

6. For power used from any city-owned hydro-facilities.

7. For new construction work, such as (a) lands purchased for water utility purposes; (b) machinery or equipment purchased outright; (c) laying of all transmission or distribution water mains (including both labor and materials).

8. Maturing interest on general obligation bonds issued for water utility purposes (the check for this interest would be made payable to the city).

9. For paying any general obligation bonds issued for water works purposes (checks payable for these bonds would be made payable to the city and charged to "Advances").

10. For paying interest and principal for any mortgage bonds which may mature and which are a direct lien on the water utility property.

11. For local and school tax equivalent accruals.

Good water works management is created—it does not just happen. No matter how small the water utility, it cannot afford not to have good management. The experience of the Wisconsin Commission, in contact with all types of water works management, leads to the conclusion that the most satisfactory form of top management is that of the special Board of Water Commissioners provided for under Section 66.6(10), Statutes. The overlapping terms of the three, five or seven members prevent upsets by wholesale political appointments and begets decidedly efficient results. Experience proves that cities in Wisconsin have attracted to the water commissions some of the best qualified men of the community. About half serve without compensation other than the satisfaction of a job well done. Others receive only nominal pay.

The water board is an active body—a board of directors, so to speak. The authority of the board is limited to operating and maintaining the utility, but the commission emphasizes that in so doing the board should weigh studiously the proper relationship between the water utility on the one hand and the city on the other—a relationship which should be on the same business basis as between the water utility and its private water consumers. The utility should not receive any special considerations from the municipality which it would not receive from a general creditor; neither should the city receive special privileges from the water utility to which private customers would not be entitled.

For example, the board should keep

constant vigilance to insure that the city pays a reasonable amount for fire protection service; for service supplied to each city building; for water used in flushing sewers and streets; water used in public drinking fountains, schools, parks, cemeteries, etc.; for filling city swimming pools; flooding skating rinks, and so on. On the other hand, the city should likewise be vigilant to see that the utility pays the city an allowance for local and school tax equivalents; for rental space used for offices in the city hall; for garage space occupied in city buildings; for part of the city clerk's and city treasurer's salaries; for work done by the city engineer or city attorney if such work is performed for the water utility, etc. As stated before, the Public Service Commission endeavors to see that cities pay the water utilities for all services rendered, and on the other hand, to see that a water utility pays the city all sums justly due. The commission endeavors to prevent cities from siphoning off city water funds, and to prevent water utilities from not paying their just indebtedness to the city.

Long Tenure

The proper functioning of a board of water commissioners varies directly with the caliber of its superintendent. With but few exceptions, those water utilities operated by nonpartisan boards have been successful in securing capable superintendents and holding them for long tenure in office. In the 30 largest cities in Wisconsin only six changes in water superintendents have been made in over 10 yr. And of these six changes, four were due to death, one due to ill health, and one due to retirement on a pension. These long tenures of office by water superintendents result in a full understanding of future requirements, in the development of sound construction programs and in real fraternal feelings between water utilities in our different municipalities. Several Wisconsin water superintendents have attributed their long tenure of successful management, in part at least, to the positive aid and active co-operation of the Wisconsin Commission and its staff. In my opinion, the key to the tenure of service of Wisconsin superintendents is (1) an efficient setup of municipal water utility regulatory laws, (2) impartial application of these laws, (3) the high caliber of our Wisconsin Boards of Water Commissioners, and (4) the permeating spirit of co-operation between cities, boards of water commissioners, superintendents, and the Public Service Commission.

Water Bills and Taxes

Another Wisconsin concept is to make each class of service contribute as nearly as possible to the cost of rendering that particular service. For example, when a substantial part of water utility property is devoted to fire protection service for the city (a service that is a very material benefit to the city as a unit), then the substantial costs of furnishing this fire protection should be paid from the city's general funds.

Still another outstanding Wisconsin concept is the statutory provision that a delinquent water bill (1) shall become a lien upon the property to which the water was supplied and (2) shall be placed upon the tax roll. This provision puts a delinquent water bill on a par with tax assessments and ahead of a first mortgage. The result is an extremely low percentage of customers' delinquent bills—there are practically

no uncollected water accounts if the lien provision is enforced.

A few words as to the extension of water utility facilities. Experience has shown that often, through city council action, many miles of expensive water mains have been installed to serve a few small customers, or one large customer, at a cost out of all proportion to the benefit to be derived from such extension. Unfortunately, such action is taken by the common council because of the political prestige of some real estate promoter or owner of a large plant. This type of over-building has been almost entirely eliminated in Wisconsin by the adoption of a statute providing that water mains be assessed. This Wisconsin law, which has been in effect over 30 yr., provides that owners of abutting property be assessed for water main extensions in an amount not to exceed one-half of the cost of a 6-in. main. Under ordinary circumstances a 6-in. main costs approximately $2.00 per ft., so that the normal water main assessment is in the vicinity of $1.00 per ft., as the property owners on both sides of the street are assessed. In Madison, water mains have been assessed since 1913. During that period, the total cost of the mains installed was slightly over $1,000,000, involving nearly 100 mi. of mains; 30 per cent of this amount was assessed against the property, and the utility bore the other 70 per cent. The large portion borne by the utility is due to the fact that mains larger than 6 in. were pretty generally installed and feeder mains, duplicating the existing mains, were entirely paid for by the utility because the assessment for mains is on a benefit basis and the larger size main is not of direct benefit as far as the domestic user is concerned.

The 1933 order No. 2-U-637 prevents over-building of any type by providing that a utility must obtain a certificate of authorization for extensions. If the commission finds that such extensions will result in over-building and therefore are economically unsound, or that they will be too great a burden on the other water users, the application for certificate is denied. The commission has had to deny very few such applications. In fact, in the three years prior to Pearl Harbor, it approved many extensions, new wells, reservoirs, pumps, pump houses and water purification systems. It has also approved some twenty-odd complete new water works systems.

Water Utility Regulation

Another fine feature of the Wisconsin law provides that any group of 25 citizens can file a complaint objecting to a utility's water service or its high rates; in addition, the commission, on its own motion, is authorized to make any inquiry having to do with water utility regulation in general. Commission order U-1288 sets up certain definite standards of water service throughout the state, covering such items as quality of the water, protection from pollution, flushing, pressure, fire protection service, meter accuracy and testing, construction records, etc.

A final important phase of Wisconsin's concept of regulation is the commission's aggressive effort to see that water utilities install a sufficient number of station meters to allow the utility to ascertain the actual water pumped, filtered and delivered to distribution systems. Water utilities are urged to meter not only the individual customer consumption, but also very definitely to meter the city consumption. It is regrettable that some of the

smaller water utilities are still guessing as to the amount of their production and sale, and are able to account for only a small part of the indicated pumpages; but, in general, the great majority of Wisconsin plants operate very efficiently. In the 30 largest cities, 83 per cent of all water leaving the pumping stations passes through permanently set meters; of the unmetered remainder, about 9 per cent is used directly through hydrants in flushing, street cleaning, public construction and fire department uses; while only about 8 per cent is unaccounted for. Wisconsin's water utilities recognize the efficiency and economy of aiming toward a 100 per cent meter use—it's just plain good business.

It is particularly pleasant to state honestly and candidly that despite occasional difficulties in connection with service, accounting methods, metering, etc., there has been a remarkable absence of complaints regarding the general operation of our municipal water utilities, or the inability of a customer to secure the service that he desires. This evidences a fine grade of work by the municipal utilities, by superintendents, and by the boards of water commissioners; and demonstrates a high degree of tact in public relations. The water utilities in Wisconsin are willing to and do meet the commission more than half way.

This golden rule attitude creates prestige for municipal water utilities, reflects credit upon the regulatory body, and results in distinct advantages to individual water users in the state. The Biblical adage, "As ye sow, so shall ye also reap," summarizes and exemplifies completely the unfaltering "Wisconsin Concept of Water Utility Regulation." As a consequence, the Wisconsin Commission and the state's utilities have benefited definitely both as "sowers" and as "reapers."

ORGANIZATION CHANGES IN WATER DIVISION

Effective August 18, 1944, the following appointments were made in the staff of the Water Division, Office of War Utilities:

Harvey S. Howe, Deputy Director of Water Division
Walter L. Leach, Chief, Materials Distribution Section
Fred H. Weed, Chief, Water Supply Section
Brent S. Drane, Deputy Chief, Water Supply Section
John R. Tanner, Regional Engineer, Region IV

The other administrative appointments remain the same and are:

Arthur E. Gorman, Director of Water Division
Daniel V. McCarthy, Assistant to Director
Newton B. Lyle, Deputy Chief, Materials Distribution Section

Historical Development of the Fire Hydrant

By L. A. Jackson

THE fire hydrant is of relatively recent origin, having been developed within the past 150 yr. This fact may seem strange since fire has always been regarded as the greatest destructive agent known, and methods to combat fire have been practiced by mankind throughout the ages. There are, however, numerous and important factors that account for this seemingly slow development, and an effort will be made to trace some of the historical events leading up to present-day fire-fighting and hydrant methods.

The history divides itself into three parts: (1) the period prior to the fire hydrant; (2) the history of the hydrant practice in England, for it was in England that the insurance companies first developed organization and methods to combat fire; (3) the history of fire hydrant progress in this country.

Hand Appliances

In the beginning, hand appliances and manual labor were chiefly relied upon to extinguish fire. The early man on discovering a fire acted as we would act today. He used hand appliances and these same methods are just as effective and important now when it is remembered that all fires are small at the beginning. When action is prompt the fire may be controlled. The barrel and bucket supply continues to serve a useful purpose in industrial plants, army cantonments and all isolated structures.

Water thrown by hand from a pitcher or bucket had serious limitations and the first progressive step to improve the effectiveness of the stream

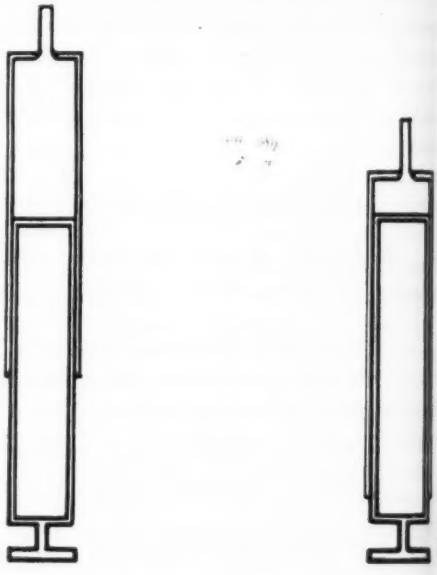

FIG. 1. Drawing of Syringe, an Early Form of Hand Fire Appliance, Described in the Writings of Heron of Alexandria, Before the Christian Era.

A contribution by L. A. Jackson, Manager, Little Rock Municipal Water Works, Little Rock, Ark.

FIG. 2. Roman Matrieuloeii "Bucket Brigade" With Fire Fighting Appliances—Hooked Knives, Siphos, Buckets and Axe.

was the development of the syringe described by Heron of Alexandria, a Greek mathematician, before the beginning of the Christian Era (Fig. 1). This instrument could well be termed the first fire extinguisher. It was a simple device consisting of one cylindrical tube fitted snugly into another cylindrical tube. By sliding the inner cylinder out, a vacuum is formed and water enters the outer cylinder through a jet at one end. When the chamber is full, the water is ejected from the nozzle by reversing the motion of the inner cylinder.

The Romans called this type of instrument a "sipho" (Fig. 2). Pliny the Roman writer (first century), and Apollodorus, Greek architect (second century), mentions the use of syringes, siphos, buckets, engines and machines to extinguish fire. Early writings record that after a serious fire in Rome, an edict was issued requiring every citizen to keep in his house a "machine" to extinguish fire. The influence of the Roman occupation of England in the early centuries is noted by the similarity of the London "squirt" (Fig. 3) to the Roman sipho. Both the "squirt" and "sipho" were developed and patterned after the syringe of Heron.

It is apparent and only natural that the early thinkers attempted to increase the range and effectiveness of the water stream. This is evident in the writings of Apollodorus who relates a method to force water to the upper story of a house. He suggests a leather bag of water with connecting pipes to the upper part of the building, and by squeezing the bag force water to discharge from the ends of the pipe. This crude arrangement could well be termed the first sprinkler system.

Even after the introduction and use

of pumps, methods were devised to reach the seat of the fire more effectively. One of these inventions (1723) was a water bomb which exploded when thrown into a burning building spreading the water over the fire.

Methods of Water Distribution

Probably the greatest influences in the development of the fire hydrant were the methods used to distribute water. The early water systems transported water under low head, and it was not until late in the eighteenth century that street mains were constantly and sufficiently charged.

Low service under very moderate pressure or without residual pressure at the point of use, is still practiced in many countries. Under the low service method of distribution, fountains, reservoirs, cisterns and public baths furnished water requirements.

As pipe materials and jointing methods improved, pressures were increased and the method of distributing water was changed from low service to pressure service. At first, pressure service was intermittent in character and was so practiced on the Continent and in England. Under this arrangement, water service was only available at intervals, was entirely unsatisfactory and soon gave way to constant high-pressure distribution.

Pumps

The use of pumping equipment had a considerable influence on the development of the hydrant. The hydraulic theory of pumping water was known before the Christian Era. History relates that pumps were used by the early Greeks and Egyptians for military, irrigation and other purposes. There does not seem to be any early reference where pumps were used for fire fighting unless the "machines" or "engines" mentioned in Roman writings of the first century referred to pumps.

History records that pumps were used in the sixteenth century in cities on the continent and in London. The earliest pumps were patterned after the syringe (Fig. 4). Manual effort was required to fill the pump cylinder and eject the stream and the flow was not continuous. It is interesting to note from the illustration that women assisted, and even as this is written women again are engaged in combating fire in war-torn Europe. The machine cylinder had a capacity of approximately a barrel of water and the entire carriage had to be maneuvered into position to direct the stream in the absence of a play pipe on the discharge. "Water syringes" of a similar type were used in the city of Augsburg about the year 1518. On later models the pumps were equipped with valves, the cylinder was placed in the water compartment, and the piston was operated by hand or foot levers, and the water was discharged through a flexible pipe (Figs. 5, 6, 7).

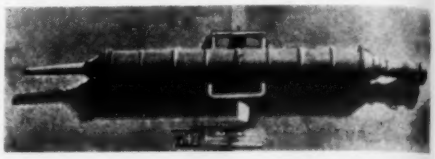

FIG. 3. London Squirt, England, Seventeenth Century.

The illustrations serve to denote pump progress. These engines are operated by lever action and have play pipes for directing the stream. A jet 40 ft. high was claimed for one engine (Fig. 5), and a jet 165 ft. in height was claimed for another engine (Fig. 6). It was said of Newsham's engine that the inventor contributed

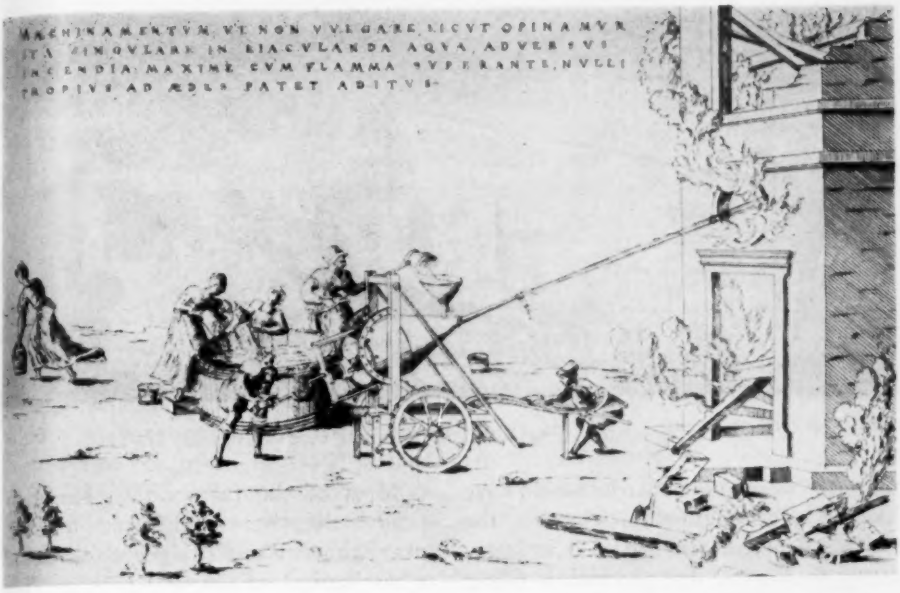

FIG. 4. Syringe Type Fire Pump. Lucar's Engine from Besson's "Instrumentorum" (French Edition) 1578.

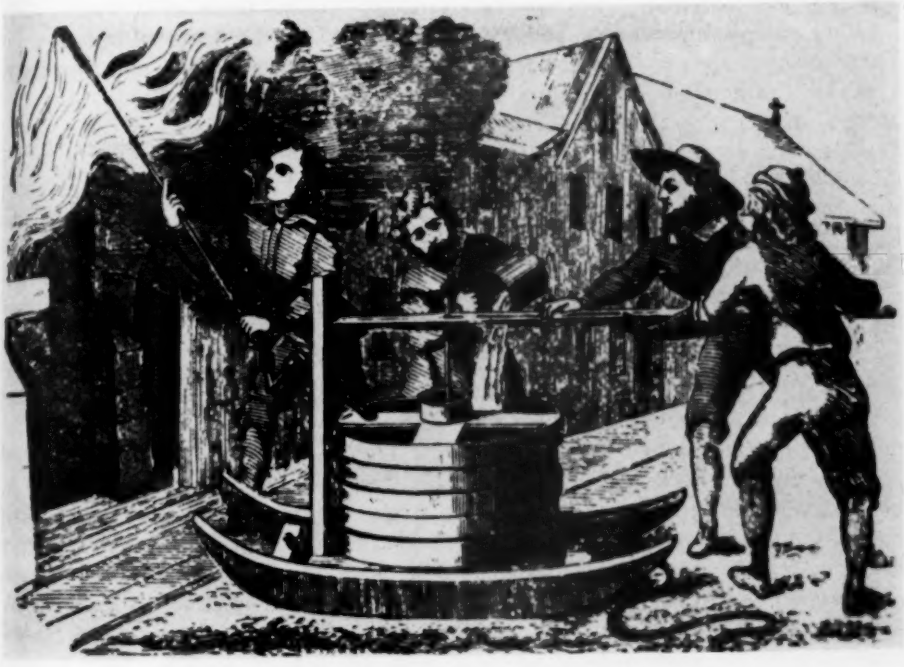

FIG. 5. German Fire Engine Described by DeCaus (1615).

FIG. 6. Newsham's Engine at the Cornhill Fire March 25, 1748.

more to his country than he would have had he added a new province to the British Empire. In Fig. 6 it is interesting to observe that the man is filling a bucket from a water hole in the street. This water probably comes from a wooden water main in which a hole has been bored.

Other pump improvements followed. These included the air chamber (1656), a device designed to furnish an unbroken stream, and the pump suction (1698), an improvement that eliminated manual feeding of the pump chamber. In this same period Jan Van Der Heijden, a Dutch engineer, and fire chief of Amsterdam, developed leather hose and put it to practical use as suction and delivery pipes for fire engines.

Steam fire engines first made their appearance in the 1820's, but it was not until the latter half of the nineteenth century that they came into general use. Insufficient water distribution facilities may have been in part responsible for the slow progress of power-driven pumps. The use of power-driven engines was responsible in a large degree for improvement in hydrant construction.

Most of the factors thus far mentioned that have influenced fire hydrant practice and design have been of a mechanical or physical nature. The great fire that destroyed a large portion of London in 1666 and the subsequent formation of insurance companies soon afterwards, were two events that had a forceful influence on fire-fighting equipment and fire-fighting methods.

Influence of Fire Insurance Companies

After the London fire an effort was made to provide buckets, squirts, ladders, etc., and provide men for voluntary brigades in each of four sections of the city. Communication was difficult, training was poor, community interest waned and fire brigade made little or no progress.

The public seemed more interested in recompense for fire losses and in strong insurance companies rather than in organization and facilities to protect property and reduce fire losses. About 1700 the insurance societies took over, at their own expense, the problem of fire protection, and formed brigades, which operated for the bene-

fit of the stockholders and the policyholder, rather than for the protection of the public at large. Competition was encouraged among these company-supported brigades with the result that their work was effective—fire losses were decreased and the enterprise proved profitable to the insurance companies. Plates called "Fire-Marks" can still be observed on old buildings, a sign signifying to the brigade that the building was insured and entitled to protection.

This scheme of independently operated brigades supported by each insurance office continued in London until 1832. In 1833 ten companies grouped their facilities and formed the first London Fire Establishment. Approximately 30 insurance companies contributed by the year 1866, when the personnel and appliances of the establishment were taken over by the Metropolitan Board of Works, and the new organization was called the Metropolitan Fire Brigade.

Development of the Fire Hydrant in England

History records that spring water was first brought into London through lead pipes and conduits in the thirteenth century. Between the years 1606 and 1620 many pipes were laid in the London area. These pipelines were made by boring out wooden logs, a method known and used for many centuries. This type of pipe material

FIG. 7. Newsham's Engine From Grantham 1792. Picture by S. G. Gamble 1878.

and the method of joining pipe sections together would not permit very high pressures. As a result, low-pressure service was practiced on these early systems and the practice continued until the nineteenth century.

Prior to the great fire of London in 1666, regulations required a barrelful of water at the entrance of each building. This meagre supply was most likely supplemented by cisterns and reservoirs.

Other steps were taken to reduce fire losses. History relates that about the year 1195 a law was enacted requiring "party walls" between residences to prevent spread of fire and again during the reign of Queen Anne (1702–1714) reference is made in an Act of Parliament to "party walls" and to insufficient water in the street mains.

The first effort to obtain water direct from the street main for fire purposes was very crude. First a hole was dug in the street and the water main located; then a hole was bored in the wooden main and the water was collected from the street hole either by bucket or suction hose and fed into the pump. After the fire was extinguished, a wooden plug was driven into the hole and the street surface was restored (Fig. 8).

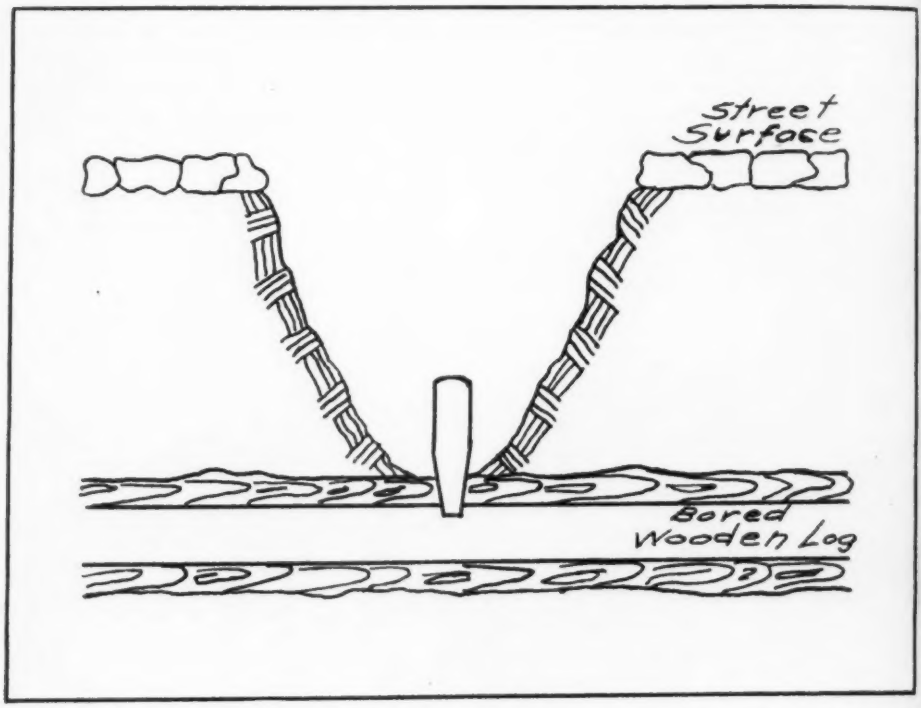

FIG. 8. Street Excavation and Wooden Water Main With "Fire Plug" in Place.

The use of a wooden plug in this manner was the origin of the phrase "fire plug" a term still commonly used today. The letters "F P" are still widely used to mark the location of "fire hydrants." The word hydrant

derived from hydro (Greek: *hudor,* water) probably originated in the United States.

Trouble was experienced with this method in that dirt fouled the pump valves, streets were badly washed and, with the advent of street pavement, excavating the holes became more difficult.

plugs were inserted in these openings and a metal or wooden shield for the wooden plug extended from the main to the street surface (Fig. 9). The shield housing the plug prevented the soil under the street surface from being washed away.

To prevent excessive waste of water and also provide a more constant flow

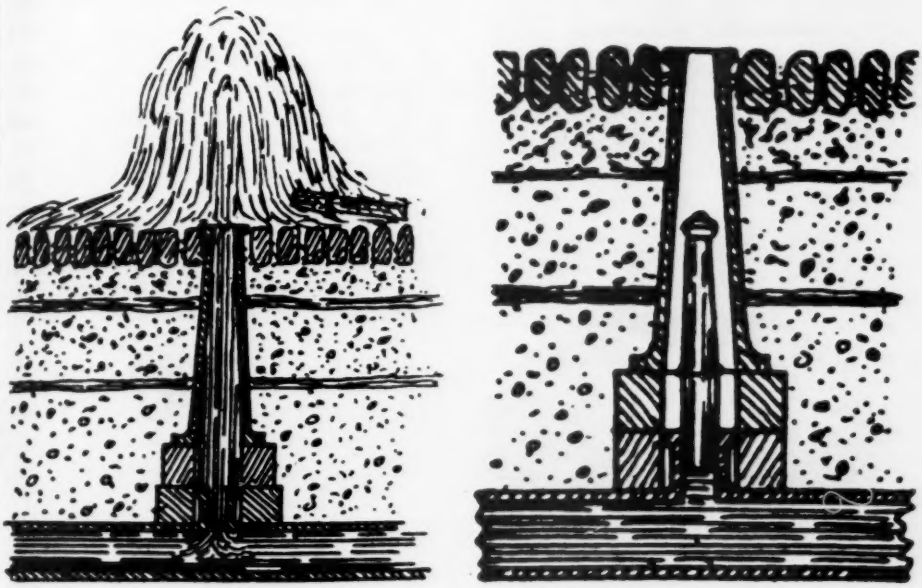

FIG. 9. "Fire Plug" in Cast-Iron Socket and Water Flowing to Street Surface After "Pulling the Plug."

The next improvement of "fire plug" design followed the introduction of cast-iron pipe. Although cast iron had been used for water pipes in France since the year 1664 it did not come into general use for water mains until the beginning of the nineteenth century. With the increased use of cast iron, sockets or branch fittings with openings were placed at intervals in the water mains. A later law (1847) prescribed that these fire plug sockets be inserted in the water mains at intervals not to exceed 300 ft. Wooden

to the pump suction the next development was the use of the canvas cistern in the year 1820 (Figs. 10 and 11). Some of the early practices are still in use. The canvas cistern arrangement is sometimes used when the location of the fire is at great distance from the hydrant. More recently, the canvas cistern has provided a source of water supply for combat troops in the field.

With the increased use of cast iron distribution pressures were stepped up, and this led to the development of the standpipe with a tapered end for in-

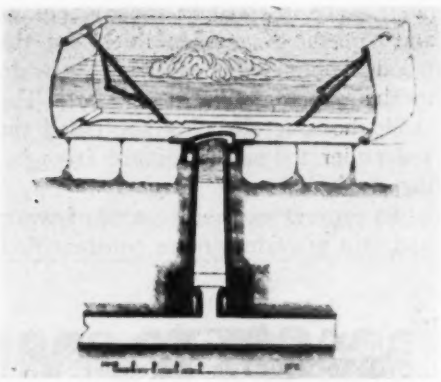

FIG. 10. Fire Plug Arrangement With Canvas Cistern.

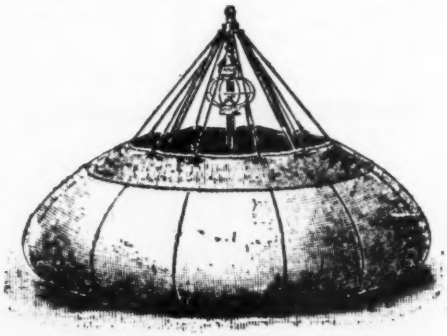

FIG. 11. Circular Canvas Dam Supported by Tripod.

sertion directly into the main and, at the opposite end, a hose connection outlet (Fig. 12). The brigades soon discarded the canvas dams, preferring to connect the hose to the standpipe in order to utilize the main pressure.

It was soon realized that the "plug type" of hydrant had definite limitations, and was practically useless under conditions of high pressure. The pulling of the plug and the insertion of the tapered standpipe against good pressure was sometimes a difficult and always a wet task. This fact led to the use of a controlling valve or cock.

In Hamburg, Germany, a connection was made to the side of the main and a stop cock inserted which was operated by a vertical rod from the street. The hydrant tube curved up to the street level where it terminated with one or more hose connections.

In England, the hydrant (fire cock) was connected to a vertical branch from the main or to an elbow attached to the main, and the whole arrangement called a ball hydrant (Fig. 13). The picture reproduced from an 1876 catalog of Guest & Chrimes, Ltd., Rotherham, England, illustrates the ball hydrant patented by Messrs. Bateman and Moore about the year 1849. The following description is quoted from the catalog:

> The Patent Fire Cocks were introduced as substitute for the inefficient Wood Plug at that time in general use. Since the introduction of these Fire Cocks in 1849, upwards

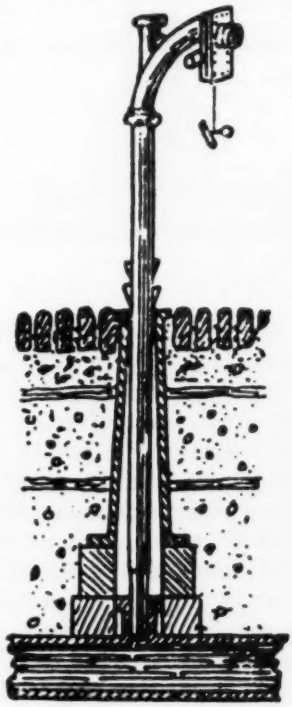

FIG. 12. Standpipe Inserted Directly Into Main Socket.

of 150,000 have been supplied, and are now in use in many of the principal Towns in the Kingdom, and abroad. Under constant high pressure they supersede the necessity for Fire Engines, as in cases of fire they can be brought into almost instant operation, with the most perfect ease and efficiency, and without any waste of water. . . .

The Fire Cock consists of a Cast Iron Box or Casing, containing a Self-acting Valve, closed by the pressure of the water. For Street purposes this casing is attached to a vertical branch, from the Water Main, or by an elbow pipe attached to the end of the Main, and when not in use the outlet of the Valve is closed by a loose cover or stopper, and the whole protected from injury by a Cast Iron Case similar to the ordinary cases or covers for protecting Street Cocks or Fire Plugs.

A serious objection to the ball type of hydrant is the fact that when pressure is taken off the main the ball drops from its seat allowing dirt to enter the main from the hydrant box. When pressure is re-established the water

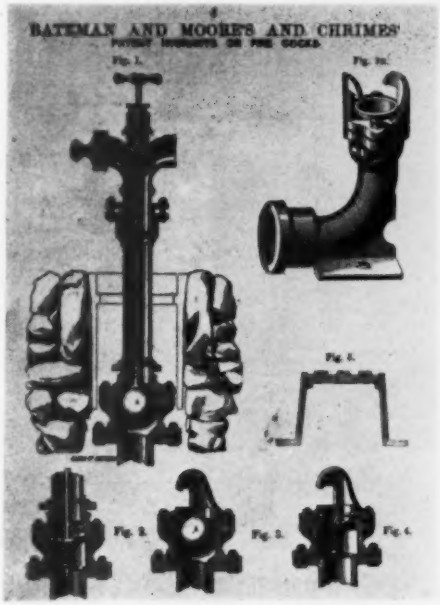

FIG. 13. Ball Hydrant, Patented About 1849.

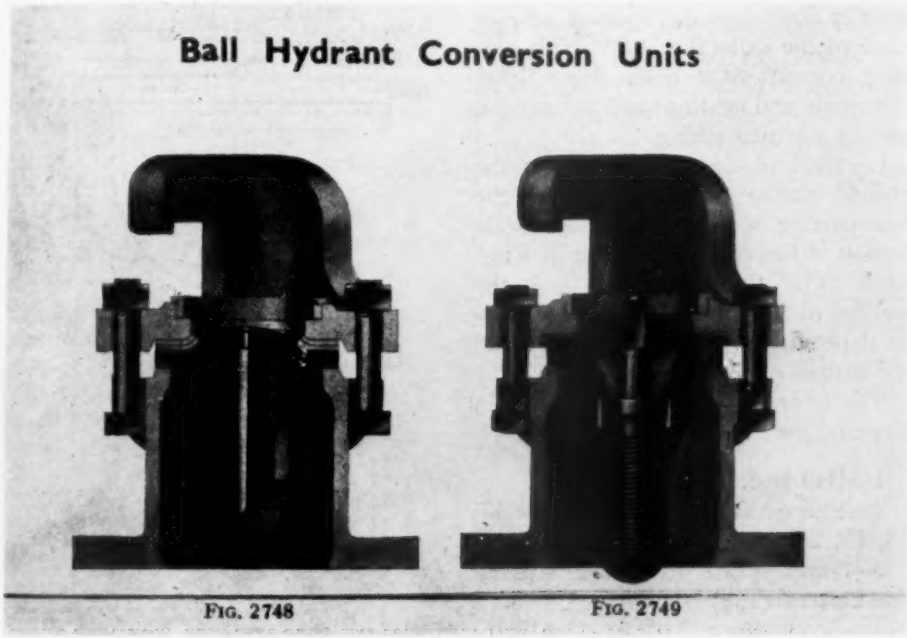

FIG. 14. Ball Hydrant Conversion Elements.

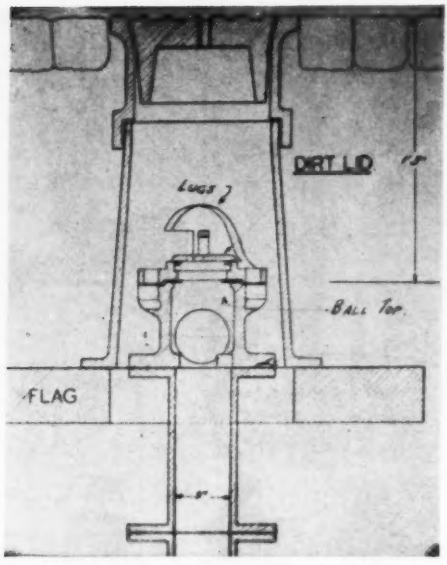

FIG. 15. Ball Hydrants.

may be contaminated. To overcome the possibility of water contamination a device known as a conversion element is fitted into the hydrant tube in place of the ball (Fig. 14). This element consists of a brass dome fitted in a guide and held upward against the seat by a strong spring.

Location of the hydrant below the ground surface (flush type) and the transporting of the standpipe or nozzle section is the current practice in England. The type of valve and the method of attaching the standpipe varies depending on the manufacturer and the custom of the locality.

The hydrants now in general use in England are:

1—Ball hydrants (Fig. 15).

2—Sluice valve hydrants (Figs. 17, 18, 19, 20).

3—Screw-down hydrants, streamline pattern (Fig. 16).

4—Screw-down hydrants, ordinary pattern (Fig. 17).

The ball hydrants are more common in the northern countries but are gradually being replaced in the interest of national standardization. The sluice valve hydrant consisting simply of an ordinary valve and a cast-iron hydrant bend is largely used in the London area. The screw-down hydrant has the valve and outlet combined in one compact unit, is designed for high discharge and is very popular throughout the country. With the exception of the ball type the hydrants above listed are defined in British Standard Specification (No. 750–1937) for Underground Fire Hydrants and Dimensions of Surface Box Openings.

The use of two types of hydrant outlets, bayonet type and threaded type

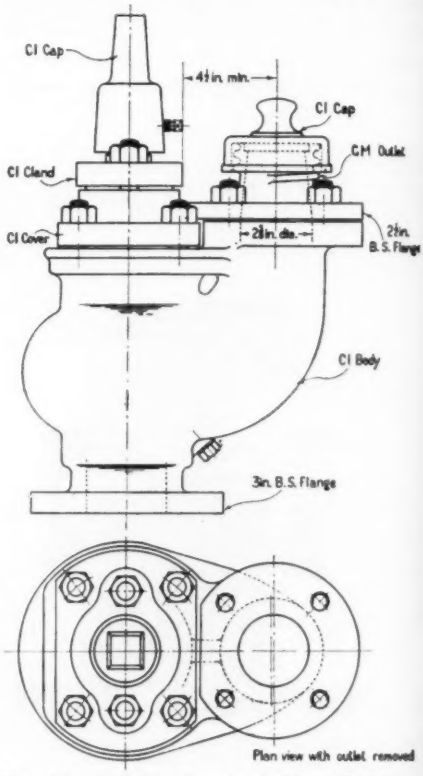

FIG. 16. British Standard Fire Hydrant, Screw-Down Streamline Pattern, Type 2.

have apparently led to difficulties under wartime conditions. National standardization is now recommended by the authorities and the specifications favor the screwed outlet with round thread (Fig. 21).

To some British engineers, the adoption of the threaded outlet as a national specification will work a hardship and financial burden on the many users of the ball hydrant with the bayonet type connection. In a letter dated January 17, 1944, Mr. Arnold C. Wildsmith, Northern District Engineer, Manchester, England, stated that the matter is not settled, but indicated that all authorities will probably be required to standardize the hydrant outlet connection.

Development of the Fire Hydrant in the United States

Soon after this country was settled, the construction of public water supplies was begun. Some of the early systems with approximate dates are as follows: Boston, 1652; Bethlehem, Pa., 1761; Providence, R.I., 1772; Morriston, N.J., 1791; Plymouth, Mass., and Philadelphia, Pa., 1797. By the year 1800 there were fewer than 20 water works in the United States.

The early fire brigades were probably patterned after the British in that they were supported by private insurance companies, or were voluntary community groups. Cities of the United States, however, were quick to recognize that fire protection was an

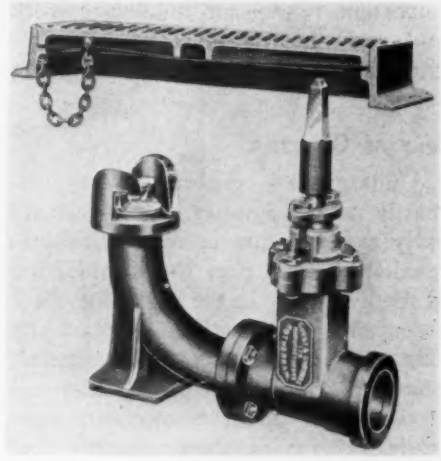

FIG. 18. Sluice Valve Type Hydrant in Surface Box.

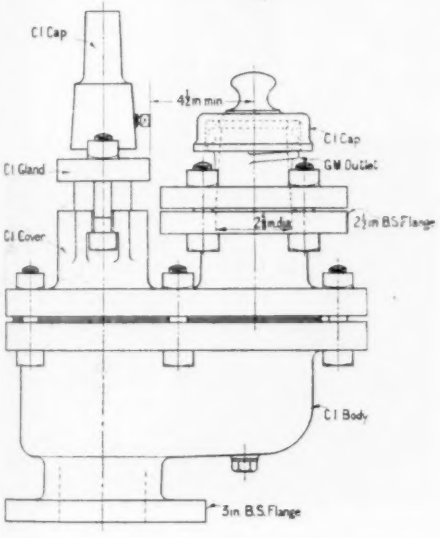

FIG. 17. British Standard Fire Hydrant, Screw-down Ordinary Pattern, Type 3.

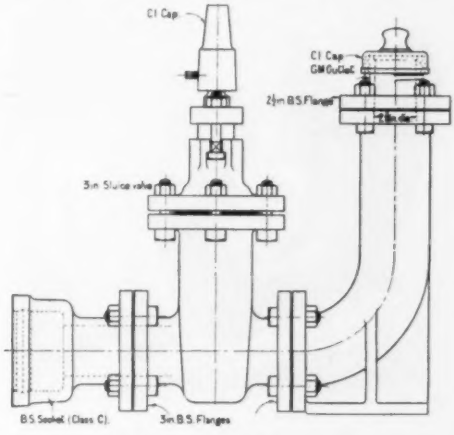

FIG. 19. British Standard Fire Hydrant Sluice Valve Pattern, Type 1.

important branch of municipal work and early in the nineteenth century cities began to take over fire-fighting service.

Use of Cisterns

Underground cisterns were primarily used as a water source on these early systems, and in many cities remained popular after the introduction of the hydrant. In the beginning these reservoirs were either supplied by rain water, or were kept full by manual pumping. With the installation of street mains direct connections were made to service these cisterns and their use continued as a supplement to hydrant service.

Statistical reports from various cities will convey a better understanding of the respective use of cisterns and hydrants.

The first mention of hydrants appears in a Philadelphia report of 1801. The following quotation is taken from the 1801 report to the Select and Common Council by the Committee for the introduction of wholesome water into Philadelphia.

> The plan of hydrants that were first used has been wholly rejected and another, which answers better, substituted. Of the latter thirty-seven (37) are now fixed in different parts of the City, and six (6) more are in readiness for the same use.

It is assumed "the plan of hydrants" that were formerly used and "rejected" were of the common plug type. By the year 1811 Philadelphia claimed 230 wooden hydrant pumps (Fig. 22) and 185 fire hydrants.

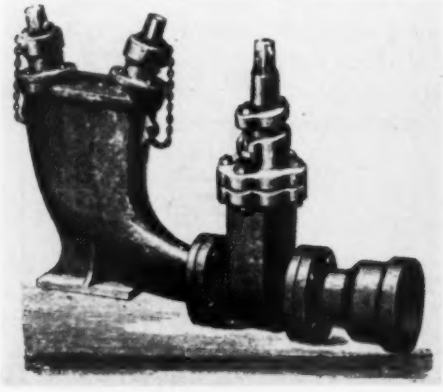

Fig. 20. Sluice Valve Type Hydrant With Two Outlets.

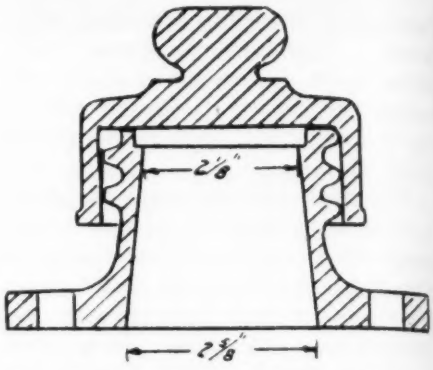

Fig. 21. Replaceable Round Threaded Outlet, British Standard Specifications.

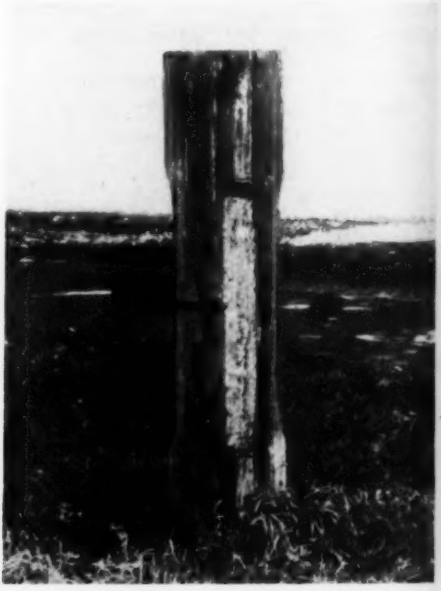

Fig. 22. Wooden Hydrant Pump, Fairmount Park, Philadelphia.

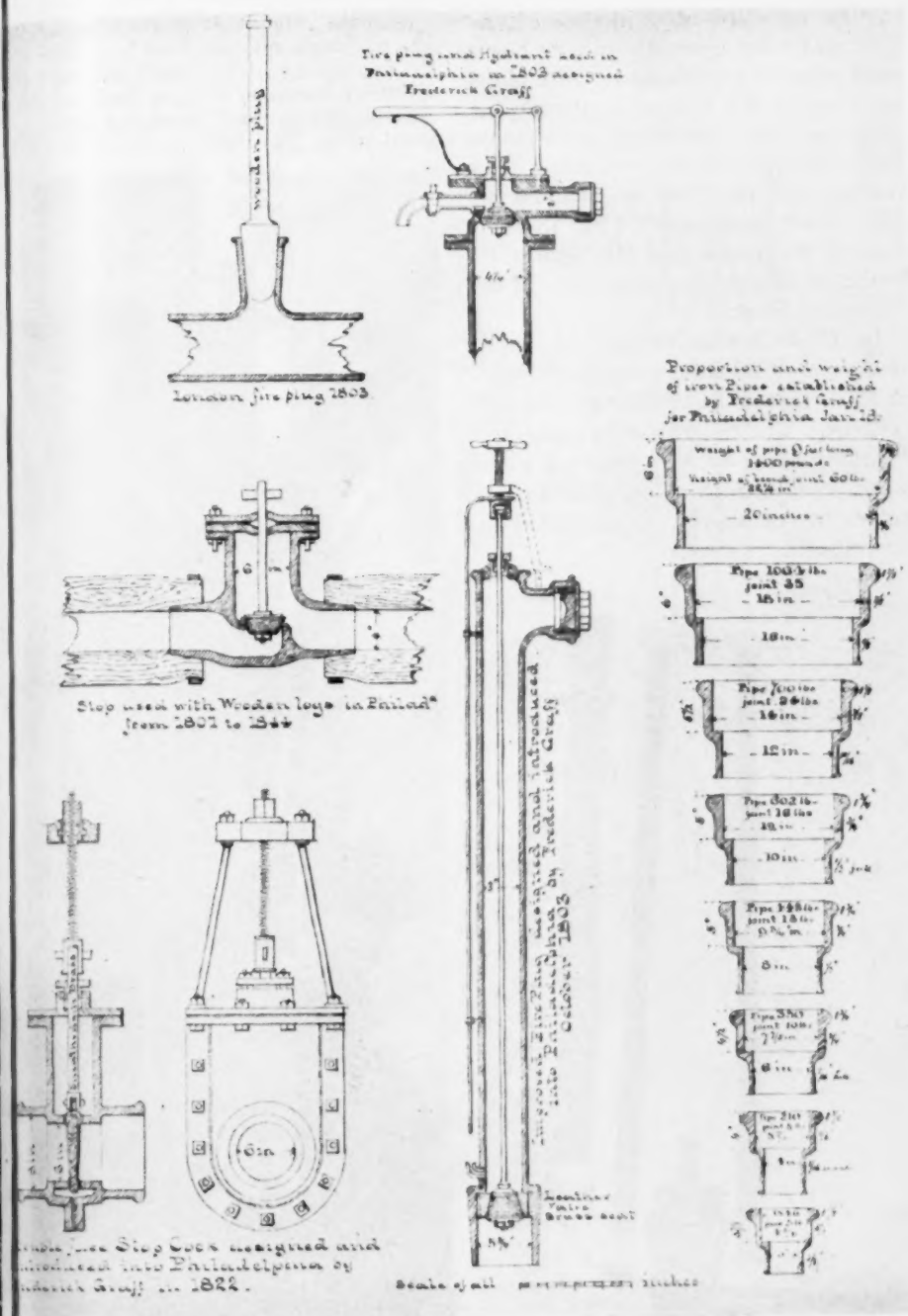
London fire plug 1803
Proportion and weight of iron Pipes established by Frederick Graff for Philadelphia Jan. 1st.
Stop used with Wooden logs in Philad.
from 1801 to 1844
Scale of all

FIG. 23. Common Plug, *Upper Left;* First Fire Hydrant, Philadelphia 1801–1803, *Top Center;* Improved Philadelphia Hydrant of 1803, *Lower Center;* Designed by Frederick Graff.

Cisterns were used in New York City and were generally of 100 hogshead capacity (6,300 gal.). Fire plugs were mentioned as used in the city as early as 1807 but these were most likely "plugs" and not hydrants. It is related that the first fire hydrant in New York was installed in 1817 in front of the dwelling of Mr. George B. Smith of Engine Company No. 12 on Frankfort Street.

In 1854 Detroit reports 65 street reservoirs in addition to hydrants; and in 1864, reports 249 hydrants, and 127 cisterns. The cisterns were connected to water mains by 3-in. lines but some were increased to 4 in. due to insufficiency of supply, as explained in the report:

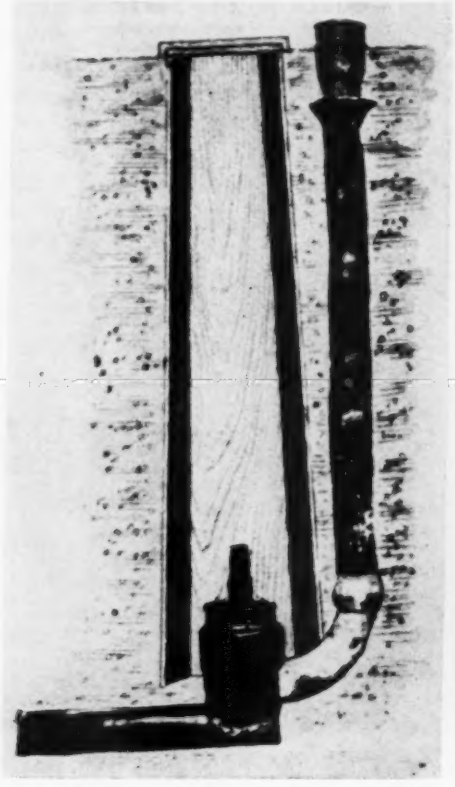

FIG. 24. Fire Hydrant, Richmond, Virginia, 1830.

Since the introduction of steam fire engines into the city, complaints have been made of the insufficiency of the supply of water in the street reservoirs in some localities; this may be remedied by introducing an additional stream into them.

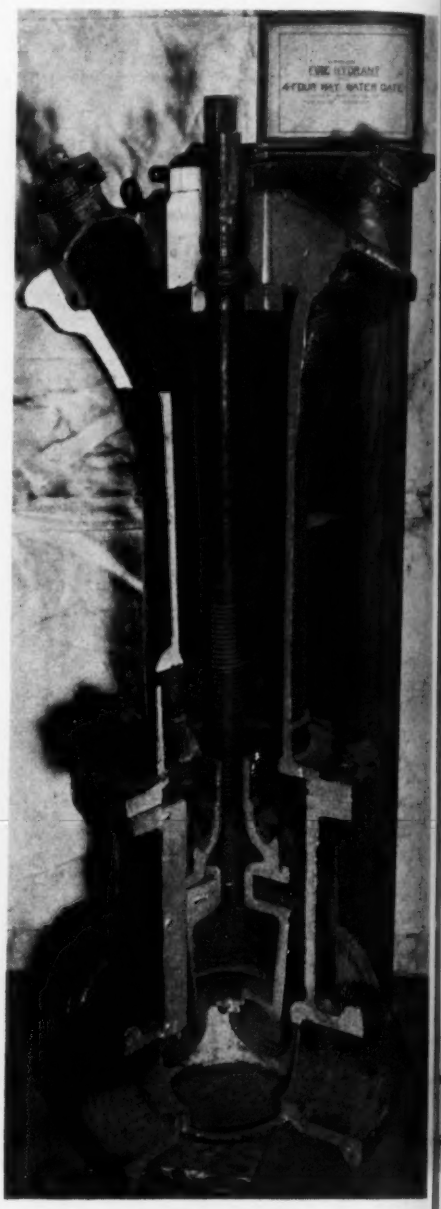

FIG. 25. Four-Way Flush Type Hydrant Probably Used in a Number of Eastern Cities. Make and Date Unknown.

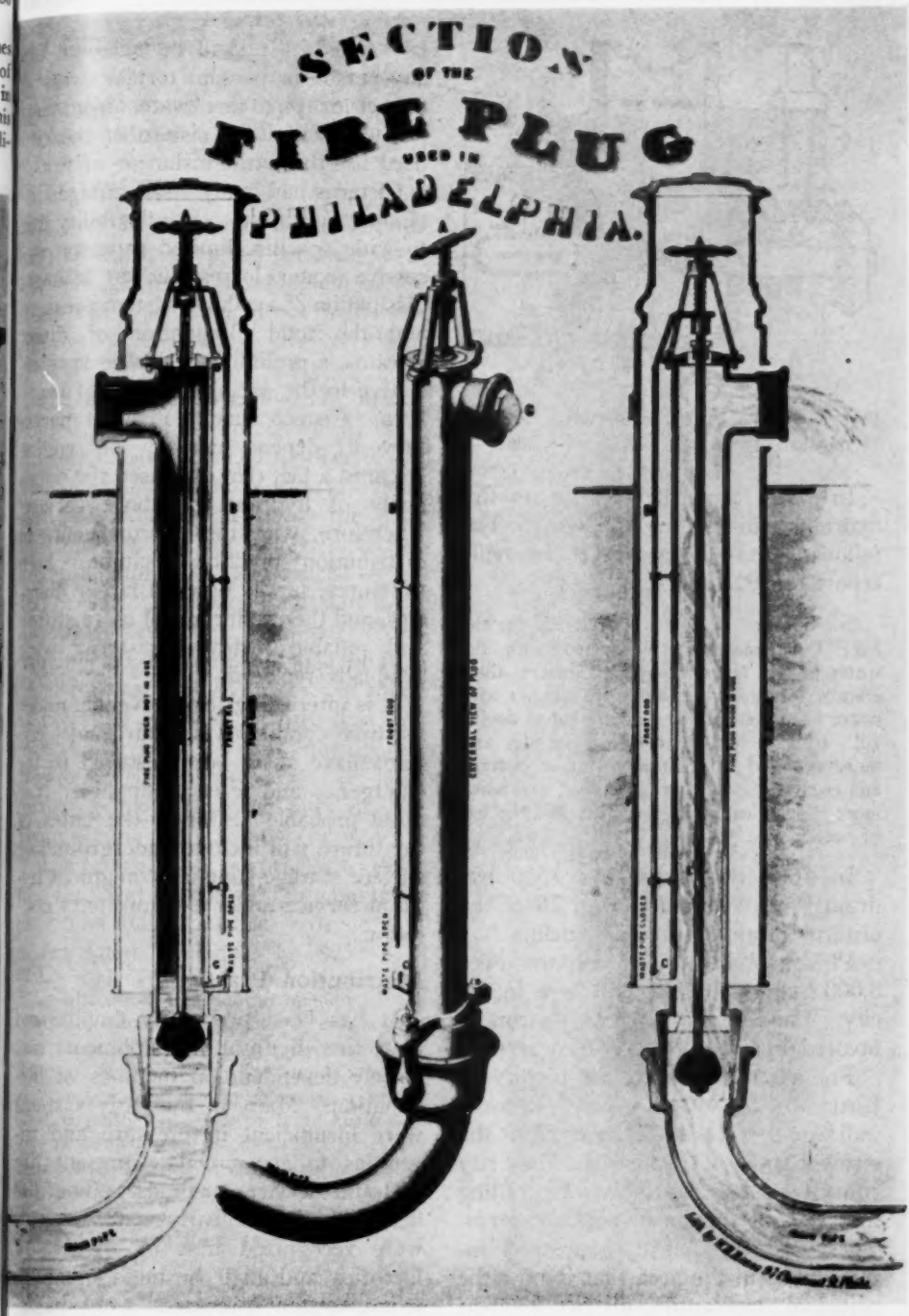

FIG. 26. Section of Fire Plug, Philadelphia (Jan. 15, 1854), When Frederick Graff was Superintendent of Fairmount Water Works. Similar to the Philadelphia Hydrant of 1806, Except That It Has a Hydrant Bend From the Branch Main, Into Which Its Base Is Leaded and Held by a Clamp Collar and Lugs, and the Frost Rod Is Worked by the Screw Shaft Instead of by Hand.

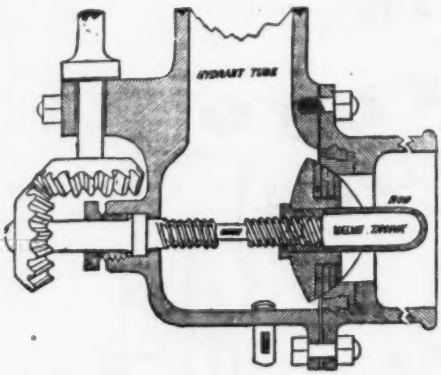

FIG. 27. Type of Hydrant Valve Recommended by Samuel McElroy in 1865.

In 1861 Louisville reports no fire hydrants and 124 street cisterns. The following extract from the Louisville report of 1861 is interesting:

> One hundred of the street cisterns for the Fire Department are connected with the water pipes. No fire plugs are in use, their efficacy for supplying steam fire engines with water has heretofore been regarded as doubtful. In some of the Eastern cities they are, however, used in addition to street cisterns and regarded as equally efficacious, and much more economical in construction and the use of water. . . .

In 1864 Boston reports 1530 hydrants and 96 cisterns with 15 of the cisterns connected to water mains.

Philadelphia, in 1865, reports over 3,000 hydrants of the post type in the city. Philadelphia apparently strongly favored hydrants over cistern service.

For a final example, the history of Little Rock, Ark., is given. Records indicate that in 1837 soon after the city became incorporated, the city council passed an ordinance calling for the construction of public cisterns. These were located at most street intersections in the area that is now the principal mercantile district. Great care was taken to protect these supplies for the purpose intended since the law stated: "It shall be unlawful for any person or persons to take even by bucket or pipe any water from any public reservoir or cistern of the city used for the extinguishment of fires."

Cisterns had many disadvantages including high first cost, inflexibility due to wide spacing, limited capacity, excessive water losses due to leakage, dissipation of available system pressure and the total elimination of direct streams, a preliminary service very effective in the extinguishment of many fires. Cistern service made it necessary to depend entirely on engine streams, a fact that increased the popularity of hydrant and hose service. Therefore, with the improvements in distribution practice, including high pressures, supply pipes of larger diameter, and the production of more sturdy and reliable hydrants, cisterns were gradually replaced.

It is interesting to observe that under wartime conditions and air raids, cisterns have again been resorted to for emergency and reserve supplies. It is quite probable also that the cities of the future will include underground or surface storage supplies to augment hydrant service under extraordinary conditions.

Distribution Practice

It has been previously emphasized that fire hydrant development was largely dependent on methods of distribution. Many of the early systems were insufficient in pressure and capacities to accommodate present fire hydrant service methods. The deficiencies of those early water systems were recognized first by owners of factories and high business buildings where system pressures were inadequate for fire protection. Pumps were installed on these individual premises

and the benefits were so apparent that it was not very long before high pressures were extended to entire water works systems.

Fire Hydrants

It may be said that United States led the way in adopting pressure service, and also in the development of the fixed-post type fire hydrant with control valve constantly charged with pressure.

The first post type hydrant in the United States was designed by Mr. Frederick Graff, Chief Engineer of the Philadelphia Water Works and was used in Philadelphia about the year 1801. (Fig. 23, *top center.*) It had a combination hose and faucet outlet, and was a "wet barrel" design with the valve in the top. A report dated December 6, 1802, relates that the first order for cast-iron hydrants was made to Foxall & Richards, a firm that formerly had cast cannons during the American Revolution, and had later turned to more practical lines of iron manufacture.

It is certainly not surprising to learn that the "wet barrel" design gave trouble. The difficulties are recorded in a report dated November 1, 1803:

> An alteration and, in the opinion of the Committee, an improvement has this session been adopted in the mode of furnishing the common supply. The hydrants though a very good invention for obtaining a supply of water, either in small or large quantities, have nevertheless been found liable to several objections. The easy access to them by boys and mischievous persons renders them difficult to be kept in repair; much attention is necessary to keep them free from frost in winter; and they necessarily produce a great waste of water, which in the winter season creates such quantities of ice around them as to make it sometimes dangerous to pass by them.

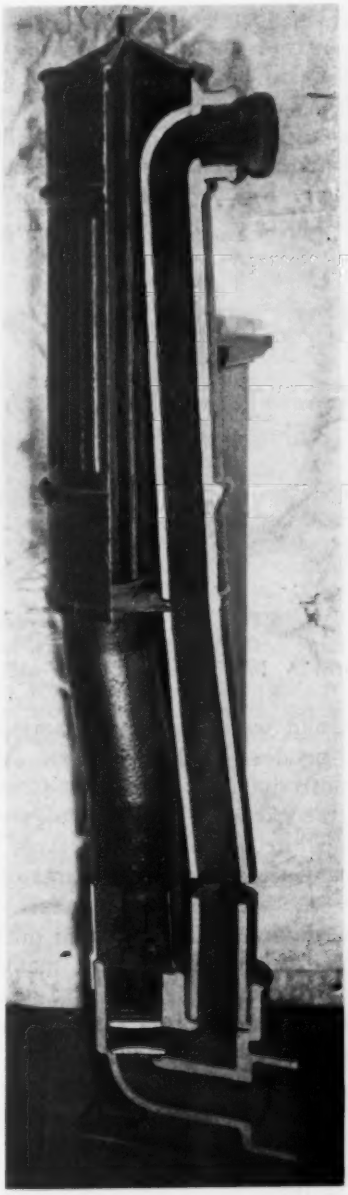

FIG. 28. Horobin Fire Hydrant. Manufactured by Horbin Machine Works, Cohoes, N.Y.

An improved hydrant with the valve at the base and facilities to drain the barrel was next introduced by Mr. Graff in October, 1803. (Fig. 23, *Lower center.*) The engraving was published October 1, 1817, by order of the Water Committee for the use of Hose and Engine Companies. These first hydrants, the forerunner of the modern post hydrant, were inserted by a tapering joint into the wooden

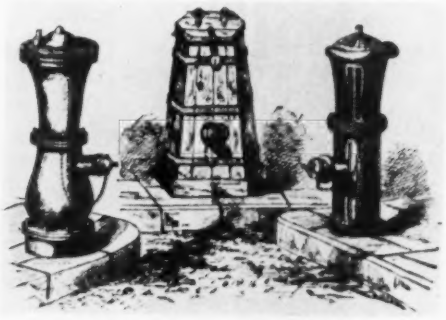

FIG. 29. Early New York City Hydrants; Right and Left, A B & C or Ayers, Manufactured by John McLean, New York.

main and were sometimes carried by the brigades, English fashion. With the introduction of cast-iron water mains, sockets or branch fittings were inserted in the line at intervals and permanently connected hydrants of the flush type became more popular.

The hydrants that followed differed in detail, depending on the manufacturer, but for the purpose of a general description the hydrant and installation included the following features:

A branch line was installed from the street main to the sidewalk to which was attached a "hydrant" bend. The hydrant was connected to the bend and terminated in one or more hose outlets either below the ground level (flush type) or above the ground level (post type). The flush type hydrant required a wooden or metal housing or hydrant box.

Two different types of early hydrants are illustrated: An 1830 Richmond, Virginia, hydrant (Fig. 24) and a four-way flush type hydrant, make and date unknown (Fig. 25).

Following the English practice the flush type of hydrant at first was the more popular. The personal whim of the fireman appears to have had considerable influence in the final adoption of the post type of hydrant. In this connection Samuel McElroy, C.E., reports in the Journal of the Franklin Institute, April issue, 1865:

> The American Hydrants, are placed along the curb lines of the sidewalk, and either "flush" with the sidewalk grade, or with "stand-pipe" heads, the former being more common in the Eastern, and the latter in the Middle States, although the water administrations of the milder sections, object to the "flush" hydrant on account of winter weather. The more correct cause for their adoption is to be attributed, partly to the habit of following certain beaten paths, without much inquiry as to their alignment, and the desire to accede to the wishes and prejudices of the volunteer firemen, who exercise considerable rivalry in securing the first hydrant for his particular "machine," and have a special regard for those more readily found in the general race of precedence. In the hurly-burly of a fire-alarm and of arrivals on the ground, a fireman looks more picturesque seated on the hydrant which he has secured for his "machine," and can maintain his position better against the next comers, than (sprawled)* over a flush case, without such salient points; beside this it takes the hose a shade easier, he thinks, and it certainly looks better in the engraving of his certificate or the elaborate art adornments of his engine and engine house.

The limitations and defects of these early hydrants were noted and recorded in the reports from the various cities. Improvements of the steam fire engine called for increased flows and

* This word inserted by author.

sturdier construction. The low temperatures of the northern cities caused great damage to fire hydrants and led to many remedies and improved hydrant construction. Insufficient flow and excessive friction were in part due to the hydrant construction, and also to the inadequacy of the feeding mains. To overcome this, larger mains were provided, hydrants were set at closer intervals and the calibre of the branch and the hydrant was increased.

The following quotations from Municipal Reports will serve to illustrate some of the difficulties encountered.

Detroit reported in 1855:

> The old waste cock and rod are dispensed with, and a small brass plug, with a quarter inch hole through the center, is driven in, in place of the waste cock. A short piece of lead pipe is soldered on to the brass plug, and connects with the drain outside of the wooden box which encloses the fire-plug. The wooden box is then filled with earth up to the nozzle of the fire-plug. Of course, a quarter-inch stream of water is wasted during the entire time that each plug is in use.

and in 1857 reported:

> . . . it will be seen that the action of frost is the principal cause of injury and damage to the fire-plugs. The fire-plugs in this city, which are the same as those used in every other city in the country, are unsuited to the severe tests of northern winters. A fire-plug that shall be so complete as to meet all the objections to the present kind, is a very great disideratum. From all places where they are used the same complaints are heard. The only remedies that appear to be applicable in their use, are to drain them (as most of them are in this city), and during freezing weather to allow none of them to be opened unless when required for use at fires.

From the Philadelphia Report of 1858:

> Great difficulty has been experienced in procuring an adequate supply of water for them (steam fire engines); this has in part been remedied by applying the suction of the engine immediately to the plug; while this gives a much better supply of water, the ram or concussion produced by the operation of the pump, loosens the joints of the plug in some of the connexions, and in one instance the main was burst; to remedy this defect and also to give a more copious supply of water, the Department has constructed a fire plug of much larger dimensions than that now in use, and which has the addition of an air chamber to it, to receive the ram of water. It is hoped by means of this that the steam fire engines can be worked without the city being put to the expense of constructing large cisterns to pump from.

FIG. 30. McClelland Hydrant (*Top*), Dent Hydrant (*Bottom*), Washington, D.C.

Philadelphia was preeminently in the forefront in the progress that led to modern hydrant practice. McElroy, states in the March, 1865 issue of the Journal of the Franklin Institute: ". . . good old, square blocked Philadelphia is ingenious in turning hydrants into suction tubes, . . ."

The annual report of the Philadelphia Bureau of Water, for the year 1865 comments at length on fire hy-

drant design and operation difficulties. Since this report is representative of many similar reports from other cities, extracts from the report are quoted:

These important fixtures (hydrants) have received much attention from the Department.

The fire plugs now used in this City are principally made from what is known as the old Fairmount pattern; and they are placed upon the sidewalk, against the curb-stone (Fig. 26).

The connections to the street mains are generally made by a four-inch branch and a four-inch pipe laid to the side of the street, where a hydrant bend is attached; this is a pipe curved up, with a tapering bell enlarged, so as to receive the fire plug or standpipe; this bend has lugs cast on it to receive the stirrups by which the plug is kept in its place.

The plug or standpipe is a pipe enlarged at the bottom to allow room for the valve, and the passage of the water around it. The valve is conical, and made of leather; it is operated by a rod passing up through a stuffing box on the top of the stand. The valve is opened and closed by a screw worked by a handle.

The valve seat is brass, secured to its place by a lead packing. The water passes out by a short branch near the top; this has a brass nut secured in it by lead packing; the nut is cut so as to fit the screws upon ordinary sized hose couplings, used by all fire companies. At the back of the plug is a rod which is lifted by the screw operating the valve.

When the plug is closed this rod is lifted, thus opening the waste or frost stop at the bottom of the plug, allowing the water in the plug to flow out. When the plug is opened the rod drops into its place and closes the frost valve, so as to prevent waste while the plug is in use. The plug is held in place by a yoke and the two stirrup bolts. The case is made of iron, in three pieces; so that it can be readily taken apart to facilitate repairs.

There are over three thousand plugs of this kind in the city, and most of the Water Works in the country use substantially the same plug.

These plugs do not answer satisfactorily for the steam fire engines, and whenever a fire occurs almost all of them used by the steamers require repairing. This pattern of plug, however, has so many good features about it, that it is difficult to improve upon it, and notwithstanding a number of patented plugs have been introduced, the one most used is substantially the same.

The department constructed a plug in 1861, when the streamers were first introduced; a number of them are in use. The difference between this and the old Fairmount plug is in the size of the standpipe and outlet, and in its furnishing accommodation for three connections; but the principal difference is in the air chamber placed outside and enclosing the standpipe; this is intended to receive the ram of the water produced by the pumps of the steamers, and prevent it from destroying the mains and other water fixtures. The steamers are now so arranged as to prevent this concussion and the air vessel is no longer necessary.

The department is now using the plug which . . . is very much like the old Fairmount plug. The alterations are in the enlarged size of the standpipe and outlet being fully equal in area to four inches in diameter. The plug is lengthened so as to place the valve deeper in the ground; the waste is arranged to draw all the water from above the valve, and the goose-neck and stands are permanently connected by flanges bolted together, instead of the socket and stirrup, as in the old plug.

This plug answers perfectly, and furnishes a full supply to a steamer; it is enclosed in the same case as the old plug, and can be substituted, as is done whenever repairs are necessary. All the new plugs now made by the department are of this kind.

On the subject of operation and maintenance, the report states:

The fire plugs are erected to be used only in the case of fire, or for flushing the gutters, when ordered by the Board of Health, the Mayor, or Committee on Water. Their use has been allowed, for filling the casks of the street sprinklers, and washing the gutters when the streets are swept. They are not intended to be used for private or any other purposes, and every use of them except the above, is in violation of law.

In this respect the laws are constantly violated, and the department finds it impossible to prevent the use of the plugs for illegal purposes. Four men are detailed for

the special purpose of looking after the plugs and seeing that they are kept in repair, but as it is necessary to detect the parties using the plugs, and sue them before an alderman, very little can be done by the Department to prevent this abuse.

If the police would take the matter in hand, this indiscriminate use of plugs could be prevented, and, as a consequence, a large amount of water saved, particularly in excessively warm days, when water is most needed for legitimate uses. Frequently, on such days, the department knows from observation, that from two to four million gallons of water are wasted by fire companies and others using plugs illegally.

During the year, it has been necessary to repair 1283 plugs, at an expense of about $8,000. Many of the plugs are wantonly broken by the firemen, who ought to be equally interested with the department in keeping them in repair. When a number of steamers are collected near a fire, they exhaust the capacity of the mains, and some of them find it impossible to procure a supply of water; at such times plugs in perfect order are wantonly destroyed.

There is, perhaps, not a single locality where over twelve steamers can be supplied with water at the same time, so as to concentrate their force upon a burning building, and when a larger number are in service they only create confusion and trouble.

Every winter some of the plugs are frozen, notwithstanding the care and attention bestowed upon them. Some years ago, it was the habit of the department to pack them with hay or straw each winter. But this was found to be no protection when the packing became wet; and when frozen, it was almost impossible to thaw them. The packing has not been resorted to for the past six years, and a less number have been frozen.

The only plugs which become frozen, are such as are so located that they cannot be drained, or where the ice is suffered to fill the gutters and overflow the pavement. In such cases, the space between the plug and case and the inside of the plug becomes filled with ice. Where vaults have been constructed and plugs exposed, they are also liable to be frozen. Salt introduced into the standpipe of plugs which are liable to become frozen, has been found a preventive, or should they be frozen, it will free them from ice.

Some of the operational difficulties experienced in the early days continue to be problems for the water works operator of the present day.

A review of the patents issued between the years 1850–1864 reveal that 15 devices were offered to improve ventage or draining, 10 devices on valve improvement, and 3 devices on frost protection. Some of the improvements suggested were quite unique, for example: A combination hose hydrant and hitching post; a combination hydrant and pump with valves operated by steam; and a gas burner built into the hydrant case to prevent freezing.

Mr. Samuel McElroy, in the 1865 May issue of the Journal of the Franklin Institute recommended a new type of hydrant valve (Fig. 27). He claimed numerous advantages for the valve arrangement and also suggested that the hydrant tube have a slight upward flare "so that in case of ice formation within it at any point above the valve chamber, the first water pressure from the opened valve would free the ice cylinder so as to permit an active thawing current out of the nozzle."

It is not known whether this design was ever actually used in hydrant construction.

In 1897 and 1898 exhaustive friction tests were made on hydrants by Mr. Chas. L. Newcomb, M.E., at Holyoke, Massachusetts. The results of these experiments were reported in a paper "Experiences on Various Types of Fire Hydrants," published in the Transactions of the American Society of Mechanical Engineers, (20: 494 (1899)). The American hydrants of that period that were tested included such names as Beaumont, Chapman, Coffin, Corey, Glamorgan, Holyoke, Ludlow, Matthews and Pratt

& Cady. As a result of these tests, friction losses were given greater consideration in the design of the water way and the hydrant outlet.

Mr. Clarence Goldsmith, for many years an active member of the American Water Works Association, has cooperated with the author of this paper, in supplying many of the photographs of early American hydrants shown herein and data relating thereto (pp. 951–956). Many years ago when Mr. Goldsmith, now assistant chief engineer, National Board of Fire Underwriters, was supervising surveys for the Board, he made it a practice to locate and photograph old (middle-era) American fire hydrants. He instructed his engineers to be on the alert for such "Industrial Americana," and at times literally "tore up the earth" to find such hydrants. A number of the fire hydrants illustrated are still in use in parts of the country; many are no longer manufactured.

The fire hydrant of 1944 is a far cry from the "plug" pulling days and the water hole in the street, but in general pattern is not so distant from the post type hydrant introduced in Philadelphia early in the nineteenth century. Distribution system methods are changing, property values are ever increasing, flow requirements are more severe, and the hydrant manufacturers, alert to these changes, are continually improving the design and construction of the fire hydrant.

References

Practical Treatise on Outbreaks of Fire. By S. G. GAMBLE. Chas. Griffin & Co. Ltd., London, J. B. Lippincott Co., Philadelphia (1926).

Public Water Supplies. Turneaure, F. E. & Russell, H. L. John Wiley & Sons, Inc., New York, N.Y., Chapman & Hall, Ltd., London (1940).

SAMUEL MCELROY. Fire Service and Hydrants. Jour. of The Franklin Institute, **79**: 81, 168, 236, 289 (1865).

The illustrations shown herein, apart from those furnished by Mr. Clarence Goldsmith, are from the following sources:

Drawings of Figs. 1, 8, W. A. Mayhan, Little Rock, Ark.; Figures 2–7, 9, 11, 12, 20, from "Practical Treatise on Outbreaks of Fire," by S. G. Gamble. Fig. 10, George W. Booth; Figs. 12 and 18, by Guest & Chrimes, Ltd., Catalog of 1876, Rotherham, England. Figs. 14 and 15, J. Blakeborough & Sons, Ltd., Brighouse, England. Figs. 22, 23, Joseph E. Gill, Principal Asst. Engr., Bureau of Water, Philadelphia; Walter A. R. Pertuch, The Franklin Institute, Philadelphia. Fig. 24, Water Works & Sewerage; Figs. 25, 28, 29, 30, Water Division, Dist. of Columbia, U.S. Government; Figs. 26, 27, Walter A. R. Pertuch.

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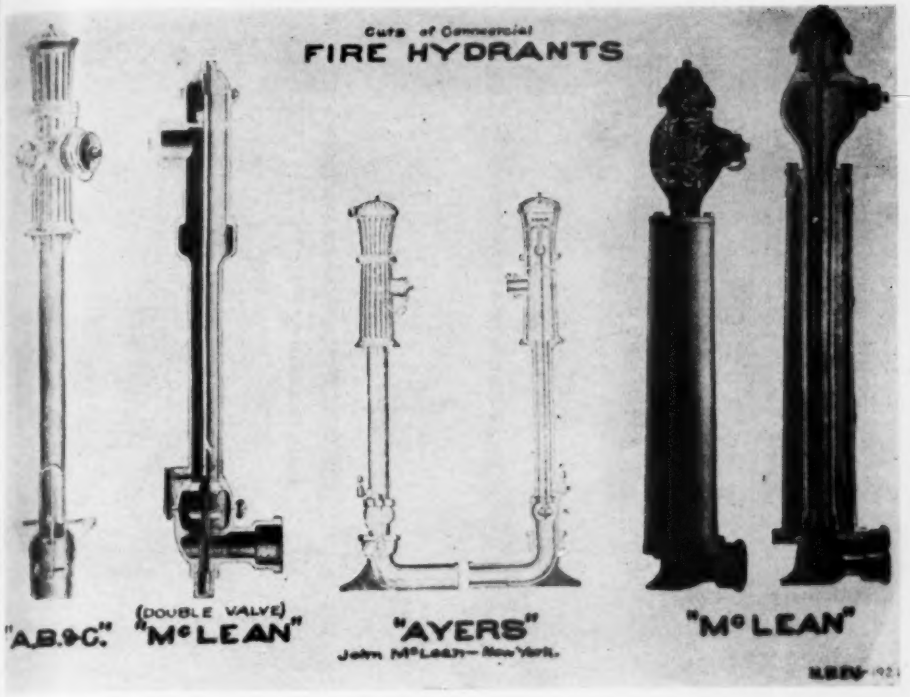
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(DOUBLE VALVE)
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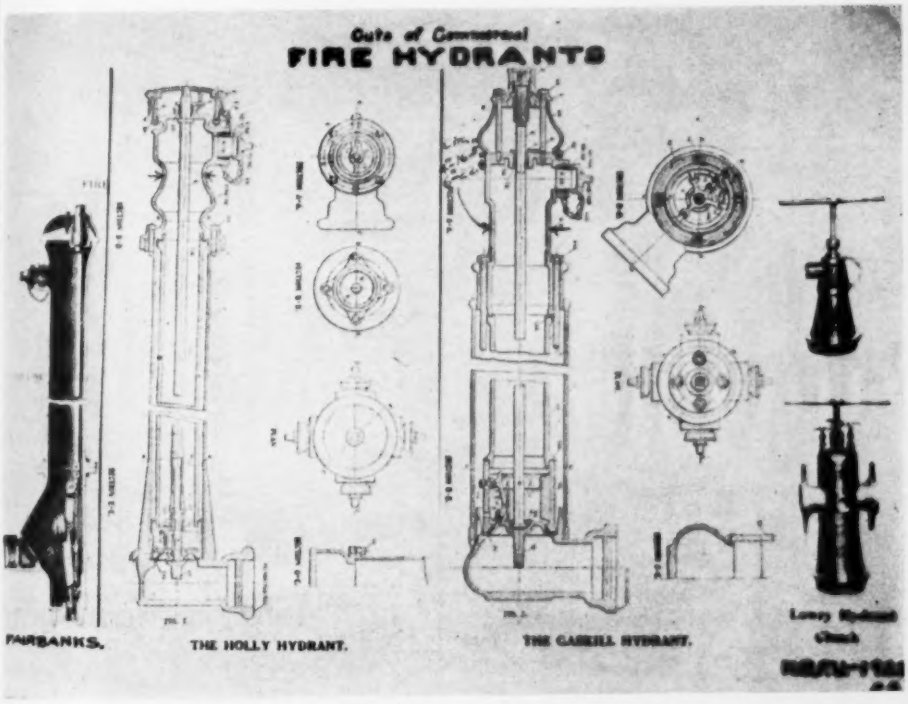
"AYERS"
John McLean — New York.
"McLEAN"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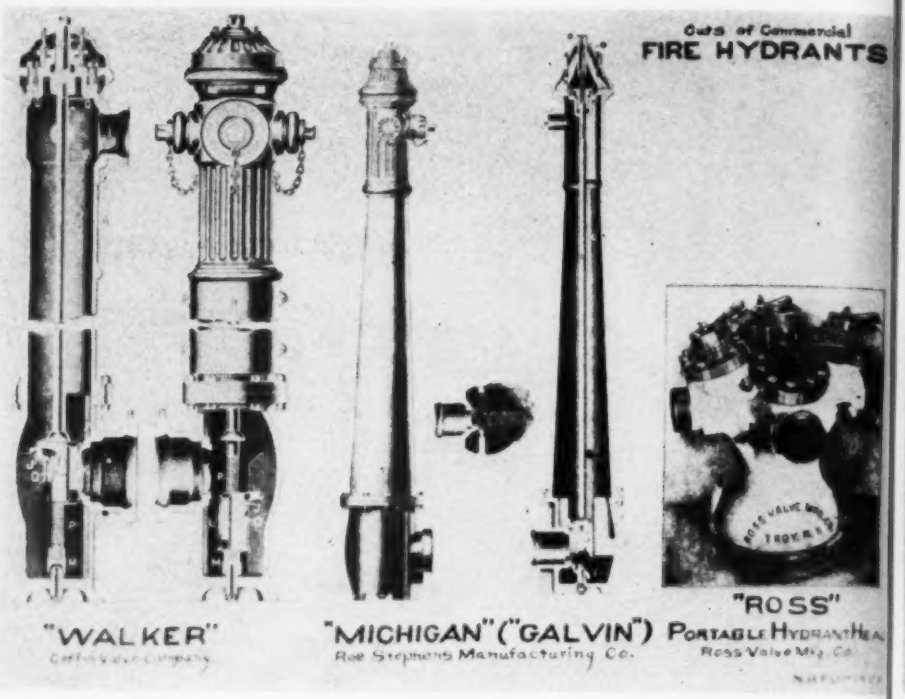
THE HOLLY HYDRANT.
THE GASKILL HYDRANT.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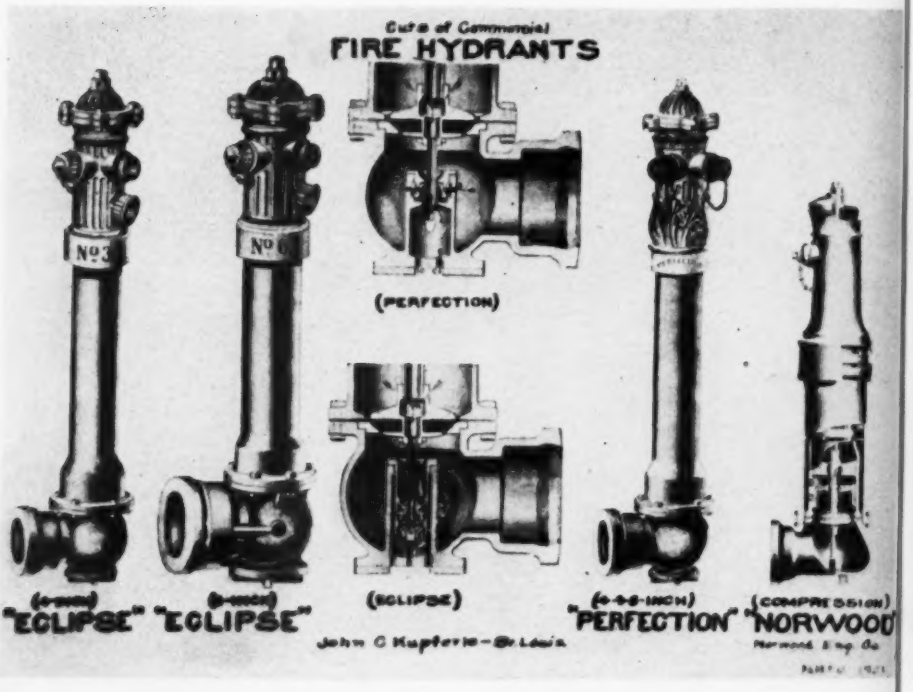
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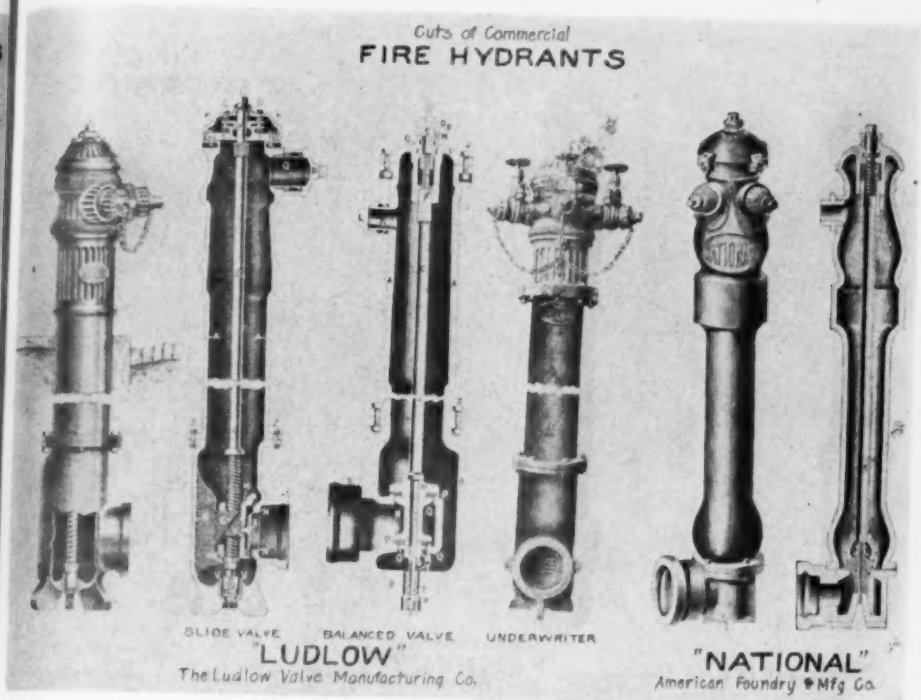
"NORWOOD"
John C Kupferle - St Louis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BALANCED VALVE
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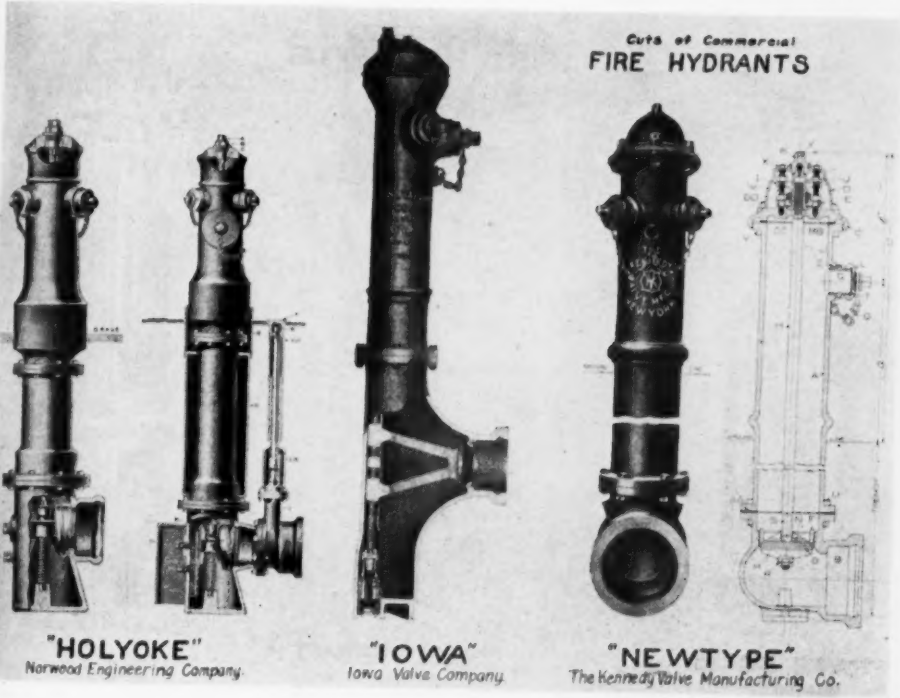
"NATIONAL"
American Foundry & Mfg Co.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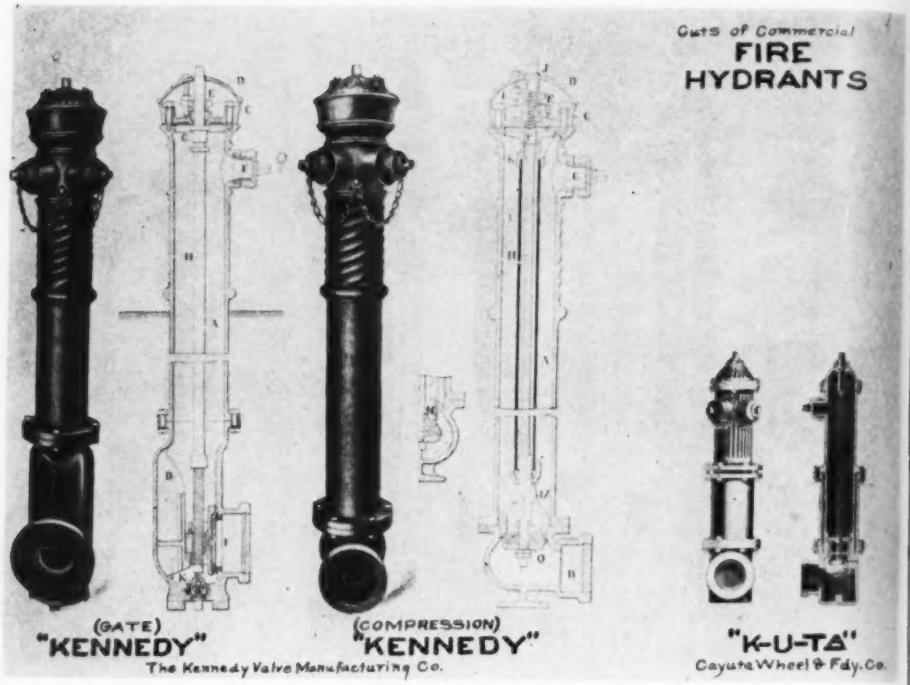
"IOWA"
Iowa Valve Company
"NEWTYPE"
The Kennedy Valve Manufacturing Co.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(COMPRESSION)
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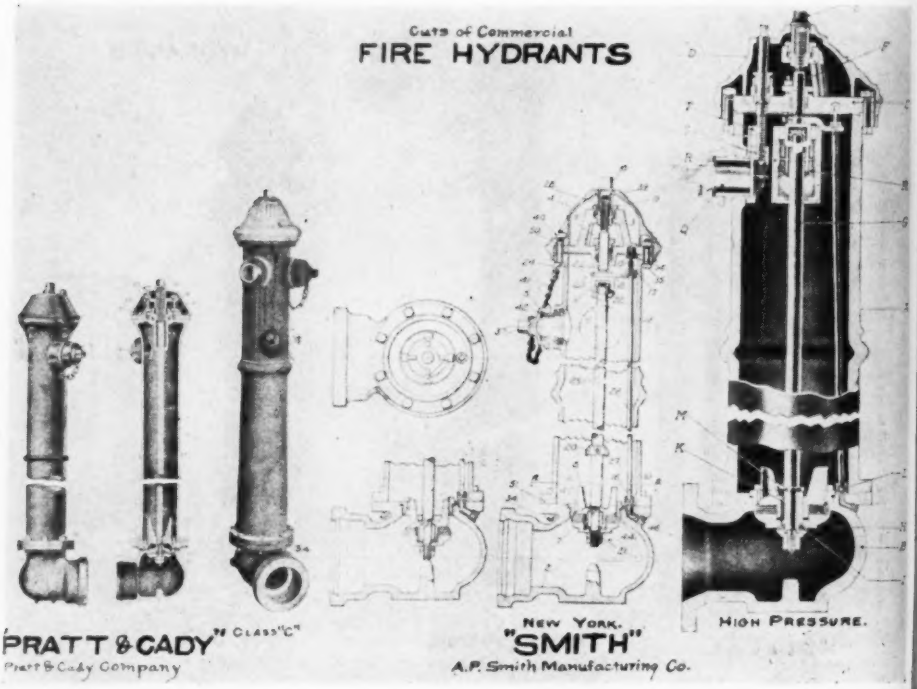
Cayuta Wheel & Fdy. Co.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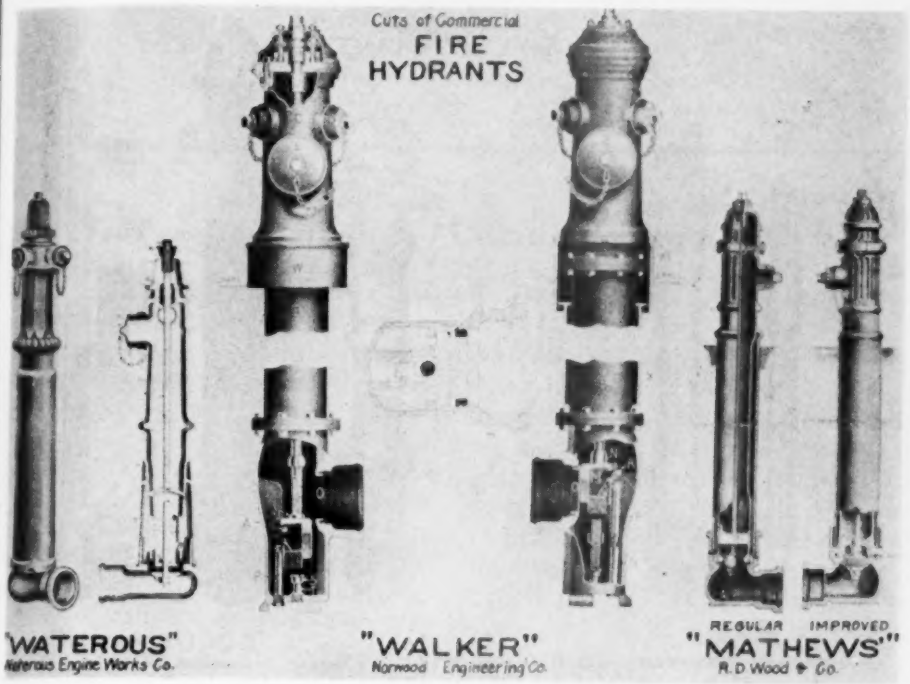
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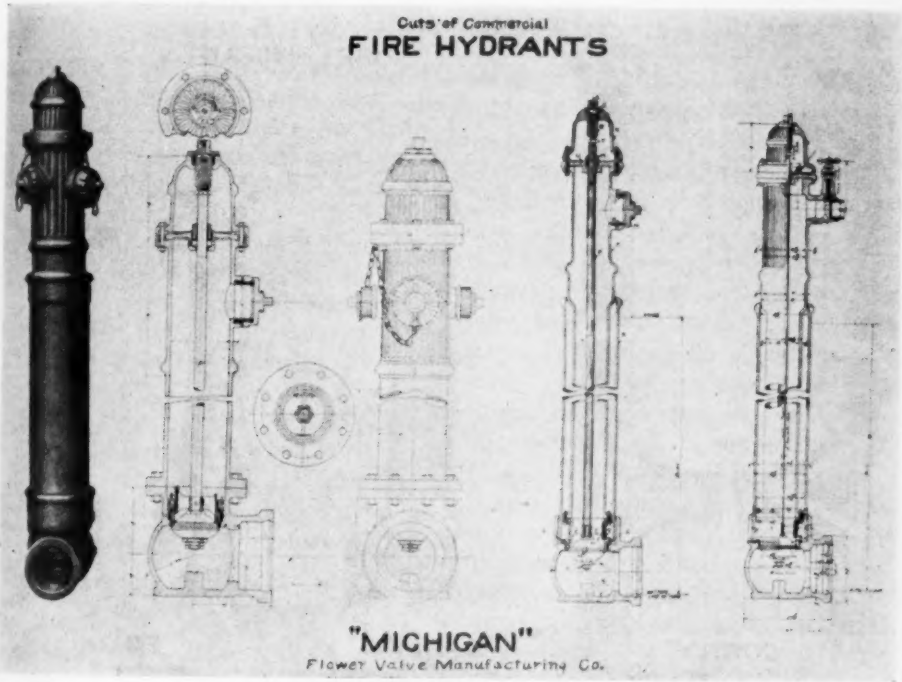
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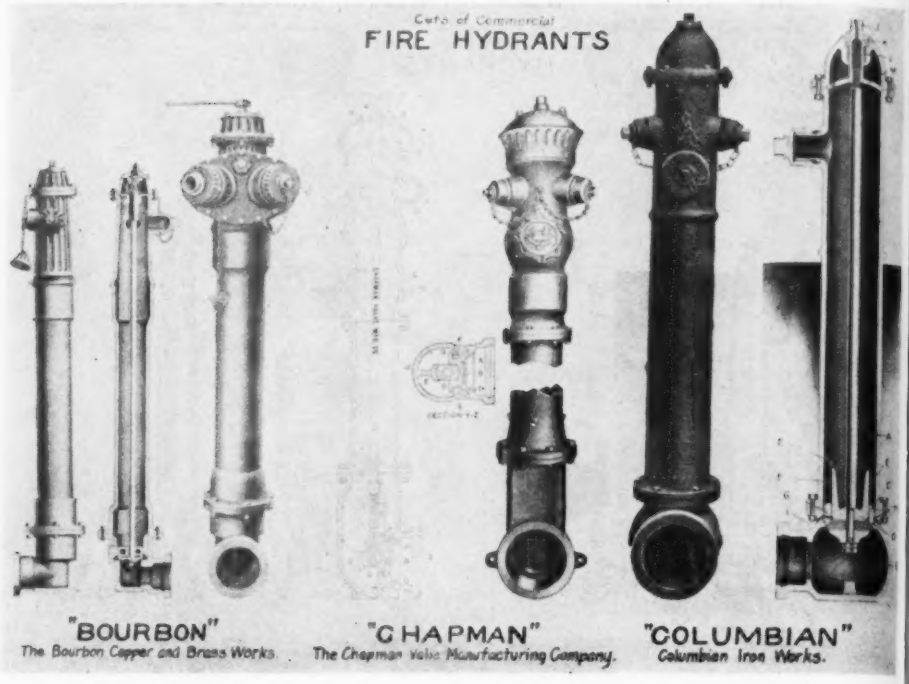
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"CHAPMAN"
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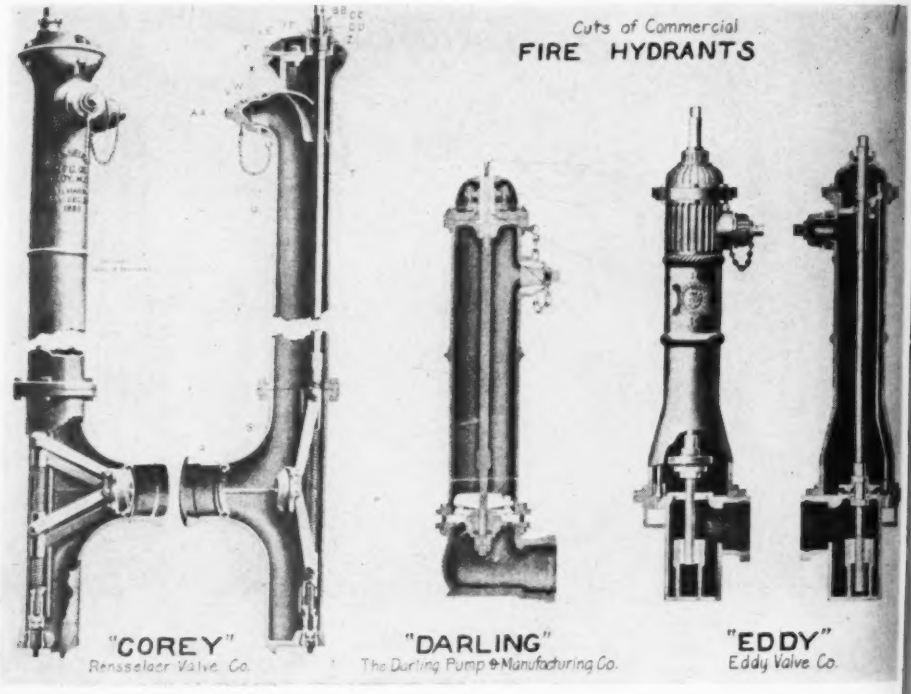
"COLUMBIAN"
Columbian Iron Works.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The Darling Pump & Manufacturing Co.
"EDDY"
Eddy Valve Co.

Practical Studies of Distribution Systems

By George W. Booth

IN normal times there are over a hundred engineers throughout the country who are regularly making detailed studies of water supply distribution systems. They are recommending the installation of mains to provide the necessary pipe capacity to prevent undue pressure losses under domestic consumption demands; they are suggesting installation of suitable elevated storage; and they are advising as to the fire flow needed and the general strengthening necessary to obtain it.

These engineers are on the staff of the National Board of Fire Underwriters or are employed by the various fire insurance inspection boards and bureaus. In addition, there are many water works employees who are making similar practical studies of their own systems.

There is at least one engineering company which for years has been making surveys of pipelines, loss of head and amount and direction of flow. The method used is somewhat different than that of the hydrant fire flow test used by our engineers, but the results are equally positive.

The problem confronting us in practically all cases is to evaluate the adequacy of an existing system, and to determine the best method of strengthening it to obtain the desired results. To check the design of a system not yet constructed, it is of course necessary to resort to analytic methods, but such new systems are usually comparatively simple and lend themselves readily to analytic treatment.

Few of these staff engineers have ever used either the Hardy Cross method of analysis or the electrical network analysis, but most of them can and do make simple analytical estimates of the capacity of arterial mains, since such estimates, as compared to actual results, will often bring to light such conditions as closed valves, lack of network connections and seriously tuberculated mains.

The study of the adequacy of water distribution systems was started by the N.B.F.U. in 1904. For the first year, a staff of engineers in the office spent days and weeks on intricate calculations. Various textbook plans were used, and modifications adopted. Reams of paper and days of calculations were the result, but actual knowledge of the capacity of the distribution system was still questionable. It was soon evident that the strength of a distribution system could not be satisfactorily determined by calculations based on assumptions which are frequently subject to error.

A paper presented on June 13, 1944, at the Milwaukee Conference, by George W. Booth, Chief Engr., The National Board of Fire Underwriters, New York, N.Y.

The values of "C" for the larger pipes in a system may be determined through the use of pitometers, or by metering the flow and recording the drop in pressure gradient; but to do this, even for the secondary feeders, would be a major task in the larger systems.

There are other features which may produce the possibility of large errors in any theoretical calculation, whether the calculation is by the Hardy Cross, the modified Freeman, the electrical analyzer, or any other analytical system. Some of these features are: (1) the probability of some valves being closed; (2) the pocketing of air at high points in the system; (3) the fact that the records are incorrect as to connections; (4) the hourly, daily and seasonal variation as to rates of flow and; (5) the changes in both domestic and fire demand.

There are two very practicable means of determining the need for additional mains. These are water plane surveys and fire flow tests. Both are used in the preparation of the reports issued by the N.B.F.U. and in determining the reinforcement necessary.

The water plane survey involves pressures taken or recorded at various points in the system where the elevation is known, and from these a determination is made of the water plane at those points. Lines of equal water elevation can be drawn, if desired, but usually these are not necessary. Where there are marked drops in the water plane the need for special studies is indicated. These drops may be due to closed valves or to heavy local consumption. These water planes will vary from day to day and sometimes from hour to hour. To be of real value there should be recording gages at a number of places in the distribution system. With such data, for a particular hour on a day of average consumption and a day of maximum consumption, or for an unusually heavy fire demand, much can be learned.

Many cities maintain pressure recorders but few take the trouble to carry through enough of a study of the water plane to tell just what trend there is in consumption demands. However, several cities are basing their plans for extensions of the arterial system largely on such water plane studies.

As already stated, the engineers of the N.B.F.U. first tried to use analytical methods on which to base their recommendations for improvements to the distribution system. In less than a year's time it was realized that this was impracticable for our purposes, and some other and more practicable way must be found. With over 450 cities of 25,000 or greater population the expense of spending months in a city was too great if these places were to be visited as often as once in ten years. There was nothing in the literature on the subject that appeared to be helpful. The use of a pitometer, current meter or other measuring device installed in the mains was out of the question because of the cost of installing them and the time necessary to take the observations.

The obvious answer to the question whether there was enough water at any given place was to open the hydrants and see what water could be drawn. The next step was how best to measure this quantity of water. Special calibrated nozzles with piezometer rings at the base were tried with short lines of hose, but this method was slow and clumsy.

Finally, it was decided that pitot tubes, which indicate the velocity of the stream on a gage, could be used to measure the discharge from the outlets of a number of hydrants. It was at first thought that the number of hydrants used should equal the probable number which would be used at a fire. Also, that the flow from any individual hydrant should be kept down to that which would be used by a fire engine. This meant opening from 10 to as many as 20 hydrants in many tests in the larger cities. It was obvious that the manpower required and the time expended were too great.

It was also appreciated that this would draw pressures down to a point where domestic service would be seriously disturbed. In fact, in some of the tests made in the early use of this system flow tests sometimes resulted in producing vacuums on the hill sections of a city. Because of this it is not the practice of the N.B.F.U. to drop pressures on main arteries to such a point that any section of the city will be left without water.

Fire Flow Tests

The procedure of running fire flow tests is reviewed briefly here. A more complete description is contained in a paper * presented by the author before this Association in 1924. Groups of from four to six hydrants are selected along the larger mains of the distribution system. A central hydrant, preferably taking supply direct from the large main, is selected to indicate the average static pressure in the group; at this hydrant one outlet cap is removed and a special cap, bored to permit the attachment of a 200-lb. gage, is substituted. The hydrant is opened and the static pressure recorded, before and during the flowing test. An observer is sent to each of the other hydrants in the group and the hydrants are opened; at strong points in the system either two 2½-in. outlets or one large outlet are allowed to flow, and the velocity of discharge is measured by the use of a pitot tube and a 50-lb. gage. It is desirable to limit the discharge from any individual hydrant to a maximum of about 1,000 gpm. At weaker points in the system, it may be necessary to flow only one small outlet on each hydrant.

To determine the capacity of the distribution system generally, the next step is to run fire flow tests on the hydrants surrounding an important industrial plant or in a warehouse area or in minor mercantile sections. Tests should also be run in typical residential areas. From a study of these tests it is possible to determine whether it is necessary to install an additional supply line from the source of supply, or whether extensions of the existing arteries should be made, or whether all that is needed is a strengthening of the general distribution system in any particular part of the city. From these flow tests and from a study of the water plane as determined from the static pressures taken in these groups, it is easy to calculate the desired size of pipe necessary to meet increased consumption demands of a growing territory and to provide fire flow. These tests will also indicate suitable locations for elevated storage.

A comparison of the flows obtained from these various tests will also indicate whether some important valve in the system has been left closed or that certain connections indicated on the map have never been made.

* G. W. Booth. Methods of Making Flow Tests and Their Value to Water Works Engineers. Jour. A.W.W.A., 12: 157 (October 1924).

Tests made many years ago indicated that a pitot reading taken in the center of the stream from a 2½-in. outlet gave results which were about 90 per cent of the theoretical discharge from such an outlet. For the 4- or 4½-in. outlets the figures are not so accurate and vary from 70 to 90 per cent of the theoretical. It has also been found that, instead of using pitots to measure the discharge, equally accurate results can be obtained by attaching a gage to one 2½-in. outlet of a hydrant and flowing the other 2½-in. outlet. This gage reading will be essentially the same as that which would be obtained by means of a pitot. It is thus possible for any water department to conduct a survey of its system, showing the capacity of the system at any particular point, without obtaining any other instruments than four or five good gages. The N.B.F.U. has a pamphlet which is distributed without cost in which is a table showing discharge from various sizes of hydrant outlets, using a coefficient of 0.90.

Quantity of Water Needed

Having determined by flow tests the capacity of the system at various points, the next step in the determination of reinforcing mains necessary is to fix on the quantities of water needed for fire-fighting purposes.

Several formulas have been more or less widely used in years past, but the one most commonly accepted at present is that prepared by Metcalf, Kuichling and Hawley, and described in a paper † by them in the 1911 Proceedings of this Association. This is often referred to as the N.B.F.U's formula and is the basis of the table of required fire flow in the Standard Schedule for Grading Cities and Towns which is reproduced as Table 1 of this paper. The greater capacity of modern fire department pumping engines and the facility with which they can be concentrated in almost any community throughout the country are producing heavier demands than for-

TABLE 1

Fire Flow Requirements

Population	Required Fire Flow for Average City—*gpm.*	Hours Duration
1,000	1,000	4
1,500	1,250	5
2,000	1,500	6
3,000	1,750	7
4,000	2,000	8
5,000	2,250	9
6,000	2,500	10
10,000	3,000	10
13,000	3,500	10
17,000	4,000	10
22,000	4,500	10
28,000	5,000	10
40,000	6,000	10
60,000	7,000	10
80,000	8,000	10
100,000	9,000	10
125,000	10,000	10
150,000	11,000	10
200,000	12,000	10

Over 200,000 population 12,000 gpm., with 2,000 to 8,000 gpm. additional for a second fire, for a 10-hr. duration.

In Residential Districts.—The required fire flow depends on the character and congestion of the buildings. Sections where buildings are small and of low height and with about ⅛ the lots in a block built upon require not less than 500 gpm.; with larger or higher buildings up to 1,000 gpm. is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gpm. is required, with up to 6,000 gpm. in densely built sections of 3-story buildings.

† Leonard Metcalf, Emil Kuiching, William C. Hawley. Some Fundamental Considerations in The Determination of a Reasonable Return for Public Fire Hydrant Service. Proceedings A.W.W.A. (p. 55, 1911).

merly on water works systems generally.

In an effort to fix upon economic pipe sizes in design, there is the temptation to use a much too great proportion of 4-in. pipe, which with the passage of time and the consequent falling off in carrying capacity becomes altogether inadequate for the demands made upon it, even in ordinary residential sections. That tendency to use 4-in. pipe is much less common than formerly, and the great majority of systems employ 6-in. pipe as the minimum size.

There is a definite question as to the advisability of using "in-between" sizes of pipe, such as 10-in., 14-in., and 18-in., for example. The first cost of installation would not be greatly increased by using the next larger size and the cost of maintaining the stock will be reduced.

It is often better to lay two 16-in. mains, parallel but some blocks apart, rather than a single 20-in.; the combined capacities are not quite equal to that of the 20-in., but the two 16-in. mains contribute toward a better gridiron and also toward the increased over-all reliability of the system in the event of a break. The same principle applies to arterial feeders, and it is good practice to use several pipes of total equivalent capacity than one very large artery. Table 2 is useful in this connection.

The problems that arise in water works practice are of two kinds, i.e., those of extensions into newly developed areas, and those of strengthening existing systems, many of which were designed for much smaller demands than those existing at present.

As to extensions, these are on the perimeter of the existing system, and in few cases are they of sufficient magnitude to warrant any attempt to form a gridiron. They consist mainly of dead-ends, and it may be years before any cross mains are laid. Recent studies of city systems have shown a marked tendency toward the outward expansion of cities and towns, with many instances of growth beyond the city limits, but still with a desire for city water.

Such expansions are occurring in

TABLE 2

Table Showing Equivalent Values of Pipe Capacity Figured on "H" and "W" Hydr. Slide Rule

Diameter Inches	S=1.0 C=100		Diameter of Pipe in Inches																Diameter Inches
	Quantity	Veloc.	4	6	8	10	12	14	16	20	24	30	36	42	48	54	60	66	
66	59,400,000	3.87	1592	550	257	143	88.6	59.1	41.5	23.1	14.3	7.95	4.94	3.28	2.31	1.70	1.29	1	66
60	46,200,000	3.64	1239	428	200	111.2	69.0	45.9	32.3	18.0	11.12	6.19	3.84	2.55	1.80	1.32	1.		60
54	35,000,000	3.41	938	324	151.5	84.4	52.3	34.8	24.5	13.6	8.44	4.69	2.91	1.94	1.36	1.			54
48	25,700,000	3.17	689	238	111.2	61.9	38.4	25.6	18.0	10.0	6.19	3.44	2.14	1.42	1.				48
42	18,100,000	2.91	486	167.6	78.4	43.6	27.0	18.0	12.7	7.04	4.36	2.42	1.50	1.					42
36	12,030,000	2.64	323	111.2	52.2	29.0	18.0	12.0	8.42	4.68	2.90	1.61	1.						36
30	7,470,000	2.35	200	69.2	32.4	18.0	11.13	7.43	5.22	2.91	1.80	1.							30
24	4,150,000	2.04	111.2	38.4	18.0	10.0	6.19	4.13	2.90	1.61	1.								24
20	2,570,000	1.82	68.9	23.8	11.12	6.19	3.84	2.56	1.80	1.									20
16	1,430,000	1.58	38.4	13.3	6.19	3.45	2.14	1.42	1.										16
14	1,005,000	1.45	26.9	9.31	4.35	2.42	1.50	1.											14
12	670,000	1.32	18.0	6.21	2.90	1.61	1.												12
10	415,000	1.18	11.12	3.84	1.80	1.													10
8	231,000	1.02	6.19	2.14	1.														8
6	108,000	.85	2.90	1.															6
4	37,000	.66	1.																4

every large city, and many small ones. New Haven, Conn., has had a decrease in population, but several communities of good size have developed just beyond the city limits. Others, such as Cincinnati, New Orleans, Bridgeport, Los Angeles, Detroit and Kansas City, have had such peripheral growth.

Friction Loss

The average dwelling house group, to provide fire protection, may readily require 1,000 to 1,500 gpm. This in a 6-in. pipe, means a friction loss of 5 to 11 lb. per 100 ft. ($c = 100$) which indicates that even though the present fire protection demand for scattered individual houses may not be for more than 500 gal., with a loss of 1.5 lb. per 100 ft., the time will come very shortly when a 6-in. pipe is too small if dead-ended and more than 600 to 800 ft. long, which is about the length of many residential blocks. As compared to this, an 8-in. main has a friction loss of 1.3 and 2.7 lb. for flows of 1,000 and 1,500 gal., and dead-ends of over 2,000 ft. can be supplied with normal pressures of 60 lb.

Calculations show that a gridiron of 6-in. mains gives a local loss in pressure, for concentrated flow from a group of hydrants, which is 4 times greater than it would be if the gridiron were of 8-in pipe and twice greater than with a gridiron of 6-in. and 8-in. pipe.

Minimum Size Pipe

Following this line of reasoning the N.B.F.U. has recommended: That the minimum size of pipe for residential districts be 8 in.; 6-in. pipe to be used only where it completes a good gridiron and in no case in blocks 600 ft. or more in length.

In making extensions from a gridiron system these 8-in. pipes should run as parallel lines in the direction of the probable growth, as thus they will form, when cross-connected at intervals of 2,000 ft., a basis for a very strong feed, and there will be little need of cross mains larger than those necessary to give domestic consumption. A splendid example of the effective use of 8-in. pipe in such circumstances is found in the distribution system of Seattle, Wash.

One of the biggest factors in fire protection is the changing of occupancy conditions which is taking place, usually slowly so that no one notices the increased local demands for domestic and fire supply until conditions become serious. One of the causes given for the extent of the Paterson, N.J., conflagration of 1902 was the shortage of water in extensive mill and mercantile areas which had been developed in an area with a gridiron designed for residential occupancy.

Recent studies of fire supply in connection with war industries have shown that many of these have totally inadequate supplies because of incomplete gridirons of 4- and 6-in. mains, whereas if 8-in. mains had been used as the minimum, the supply, although not ample, would have been good.

The value of 8-in. pipe, especially in parallel lines along the long side of city blocks, is again shown in considering the arrangement of secondary feeders. Three such lines have essentially the same carrying capacity as a 12-in.; thus, in a system using 8-in. pipe as a minimum there is seldom need of using 12-in. pipe except where it is needed as a distributor in a manufacturing area or along a street of mercantile occupancy where concen-

tration of fire flow of the order of 4,000 to 5,000 gal. is required.

The second phase in the design of a distribution system relates to arteries. It is almost axiomatic today that sole dependence must not be placed on a single arterial main, nor should two or more arteries be in the same street.

These feeders or arteries, because of cost, must be laid by the shortest route and to the points of heaviest demand. Such was the basis for most original designs of distribution systems, and these feeders extend by fairly direct routes to the congested value or principal mercantile district. From these large mains secondary arteries extend generally in loops or squares.

Water System Plans

Some cities adopt a master plan for these arteries with the idea of following this for all time. Anyone who has watched the development of American water systems for the past 35 yr. will readily agree that any such plan, prepared more than 10 or 20 yr. ago, will result in a large waste of money, and probably in a system inadequate for the present needs.

With large cities there may come a time when, because of a manufacturing development in the part of the community furthest from the source of supply, it is necessary to lay a large feeder from the source to the area to be served.

There has been a tendency to lay such a main along the outskirts of the distribution system, or to run it as an express main through the distribution system and take feed from it only in the area found deficient. Both practices are faulty, inasmuch as they do not adequately strengthen the system where the values are highest and the greatest protection is needed. In fact, such large mains should always extend through or connect into the heart of the distribution system, providing it does not unduly increase the cost nor put two large mains in the same street.

Elevated tanks have been used in comparatively recent years in greatly increased numbers, and in most cases to very good advantage. Improvements in design and construction and the comparatively modest cost of storage in such tanks have contributed to their more extended use. Every tank can be looked upon as a secondary source of supply for fire protection and for peak consumption load. However, the tank must connect into the distribution system by means of a pipeline of sufficient size to permit its capacity to be delivered.

On the basis of a 10-hr. fire demand it is estimated that the size of pipe used to connect elevated tanks should be as given in Table 3. These pipes should extend into the district to a point where they connect with mains providing equal or greater capacity. These sizes will allow storage in the top part of the tank to be used to take care of fluctuations in domestic demands, without an excessive drop in the pressure,

TABLE 3

Tanks—*gal.*	Delivery Rate for ½ Capacity—		Size of Connecting Main—*in.*
	mgd.	*gpm.*	
100,000	0.24*	166	6
200,000	0.48*	333	8
500,000	0.6	417	8
1,000,000	1.2	833	12
2,000,000	2.4	1,666	2–12 or 1–16
5,000,000	6.0	4,165	2–16 or 1–20

* For 5 hr.; others of 10-hr. duration.

and will provide a reasonable increase in the fire flow rate.

Elevated Storage

The question of the location of elevated storage is an important one. Primarily such storage should be in the sections of heaviest demand, either domestic or fire, and by so locating it the full benefit of the storage can be obtained without laying much additional pipe. The practice of putting storage at the extreme edge of the distribution system, or even beyond the limits of the mains, is poor, and this is especially true where there are several tanks. However, where a section is well removed from the remainder of the distribution system, or is at an elevation where the pressures are low and much fluctuation cannot be allowed, the location of a tank within or near the area is very desirable. This is particularly true of isolated factories, especially if they are dependent on automatic sprinkler protection. Under these conditions the storage can be considered primarily of local value, and the main connecting it to the major part of the distribution system need not be larger than that which is necessary to meet the maximum 24-hr. consumption requirement, which in most instances would be met by an 8-in. main. When tanks are small or of shallow depth, those located away from the central or heavy demand section of the distribution system should not, and in fact cannot, be considered as contributing to the fire flow, especially if the connecting pipeline is of large size. It can be readily seen that with unrestricted flow through a large main these tanks would be empty at such times are pressures dropped 5 to 10 lb. within the center of the distribution system.

Planning Distribution Systems

A study of the development of water systems in a number of larger cities has brought out several other items having a bearing on this question of how best to plan distribution systems. One of the most important of these is the question of where the water is to be obtained. In a period of less than 30 yr. in many cases there have been radical changes in the direction from which supply was secured. Chicago, although it has always depended on Lake Michigan for its supply, has introduced a new point of feed with each new pumping station. Albany, N.Y., has had three different sources; St. Louis, Mo., is largely developing the Missouri River supply after depending for years on the Mississippi; New York City, including Brooklyn and Queens, now has numerous centers of feed from tunnels instead of the former supplies from the local distributing reservoirs and scattered sources of supply; New Haven and Bridgeport, Conn., have undergone similar experiences, as have many smaller cities.

Increasing Pressure

With a few exceptions there has been a tendency in cities formerly classed as low-pressure cities materially to increase the pressure carried, thus allowing for a greater fluctuation in domestic demands without lowering the pressure to a point where service was unsatisfactory. This increase in pressure also provides greater fire flow.

The general idea which the author wishes to bring out is that the distribution of water depends on many factors which vary from day to day or even from hour to hour. On the average, the total quantity of water needed for domestic and fire service is so large and involves so many un-

known factors that an attempt to make a complete analytical study requires much time and effort. A more satisfactory determination of present and future needs can be obtained through the simple and practical methods cited, the value of which has been proven during the past 40 yr.

Discussion

H. E. Beckwith *

We believe that we are the engineering firm which Mr. Booth refers to as specializing in "making surveys of pipelines, loss of head and amount and direction of flow." This being so, we wish to avoid a possible misunderstanding of our work which might arise from a reading of Mr. Booth's paper. It might appear that in collecting data to be used as a basis for distribution system design we substitute Pitometer flow measurements and loss of head measurements for hydrant flow measurements and pressure gage readings. This is not so. We make the hydrant flow tests and pressure readings recommended by Mr. Booth but in addition we also make the Pitometer flow gagings and loss-of-head tests. It is a case of "in addition to" and not "instead of." In this connection we quote from a paper by our chief engineer, Mr. E. Shaw Cole, published in the JOURNAL of the American Water Works Association: †

> The actual physical condition of the distribution system is determined by various field tests and are usually made in conjunction with Pitometer flow gagings. These include loss of head tests, hydrant flow tests and a pressure survey. All results are thoroughly analyzed; and are made available for use as a basis for the design of the extentions and reinforcements and for checking hydraulic computations.

We believe that these additional gagings and loss-of-head tests are well worth while as they lead directly to the discovery of defects in design or accidental obstructions. In a recent investigation of this kind in a city of about 50,000 population four important valves on large mains were found closed. In another instance the insertion of an air valve on a 36-in. line led to the filling of a balancing reservoir for the first time since it had been built. Trapped air is a very effective seal to prevent the passage of water. Very frequently "lazy" mains are discovered which can be put to work inexpensively by increasing the feed to or from such mains. All in all, these additional tests greatly increase the knowledge of what the existing plant is doing and can be made to do.

Mr. Booth states that the determination of the value of "C" would be a task. We believe that he is speaking for his own organization, and we agree that it would be unfair to expect the Underwriters to do this work. However, many of our larger cities and outstanding engineers have found this information invaluable in designing additions to existing distribution systems. Our firm has made "Trunk Main Surveys" or "Distribution Studies" for securing this information in many of our leading cities, including Minneapolis, Newark, Milwaukee, Providence, Philadelphia, Baltimore, Pittsburgh, Detroit, Cleveland, St. Louis, Cincinnati, Toledo, Columbus, New Orleans, Dayton, St. Paul, Hous-

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* Dist. Mgr., The Pitometer Co., Pittsburgh, Pa.

† E. SHAW COLE. The Value of Distribution System Studies for Meeting Present Emergencies and Post-War Problems. Jour. A.W.W.A., **34**: 1762 (1942).

ton, and Buffalo. As the cost of these tests averages only a fraction of 1 per cent of the cost of the needed improvements, we feel that they are more than justified by the resulting economy of design.

None of the above remarks should be interpreted as a criticism of Mr. Booth's paper as we consider it one of the best ever published on this subject. Our sole purpose is to clear up any possible misunderstanding relative to the work done by our company.

W. E. Howland ‡

Without disputing the value of the experimental methods presented in this paper, I wish to state my opinion that the Hardy Cross method referred to in the paper, or simplifications and adaptations thereof, do have a useful part to play in the analysis of the behavior of actual pipe systems.

I base my opinion upon my own experience which, however, is very limited when compared to that of the author. I have used the method in the analysis of several proposed designs of fire protection systems for two large ordnance plants. These pipe systems, it is true, are much simpler than those of large cities, but I believe that the Hardy Cross method when used wisely and in such a manner as I will explain, may be helpful in the analysis of much more complicated systems. This particular method is especially applicable to systems in which the many rather small take-offs may be negligible when compared to a single large fire flow.

Briefly this method is the following: Boldly to omit cross-over pipes which are judged to carry small flows, either because of their small size or great length, or because it is thought that they connect points of approximately equal pressure. By cross-over pipes are meant those which connect with an intermediate point on a given pipeline in such a way as to prevent the use of the equivalent length pipe analysis method. § The remaining cross-overs which are judged to be important may then be replaced by two or more parallel pipes not necessarily of equal length, whose combined capacity is equal to that of the pipe replaced, and these are then joined in the equivalent pipe system in such a way as to make possible the use of the equivalent length method. It is very easy to do this by means of a chart included in the article previously mentioned. When these or other simplifications are made, the analysis of the system by the equivalent length method with the aid of the chart referred to is exceedingly simple and rapid, and one may always be sure that the computation will give an answer, which, though approximate, is on the safe side; that is to say, when this procedure is used one may be sure that the actual equivalent length of the system is less than these calculations indicate. (This assumes, of course, that no mistakes in arithmetic are made.) To know that the flows will be at least as great as a certain figure when the head loss is a given amount or, conversely, to know that the pressure drop will be no more than a certain amount for a given flow may be all that is needed to determine that the fire protection furnished by the system is adequate.

But it often happens that the com-

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§ W. E. Howland & F. Farr, Jr. Computation of Equivalent Lengths of Parallel Pipe Systems. Jour. A.W.W.A., 33: 237 (1941).

puter would like to know whether a particular simplifying assumption that he has made is not, perhaps, too conservative, or whether a particular kind of assumption is a good one, in this sense. He may always go back to the Hardy Cross method to obtain as exact an answer as he wishes to all such questions. Thus, using the Hardy Cross method as a calibration device, the analyzer may build up a fund of tricks or approximations which, for him at least, will be useful. It is well to make sure that the assumptions are on the safe side as I have explained. When these procedures are employed one may know that of several such rapid solutions of a particular problem the most precise one is that which gives the smallest equivalent length.

The approximate simplifying procedures which I have described may usually be employed to advantage at least for parts of systems even when it is decided that the Hardy Cross system must ultimately be used in the entire simplified system.

Many computers who have used the Hardy Cross method have hit upon simplifications which seemed good to them, and still other improvements have been found and will be published. The numerous articles which have appeared in the literature of this sort are evidence of the value of Professor Cross's basic and powerful method for precise solutions of what would otherwise be exceedingly complicated mathematical problems.

I can imagine situations in which a comparison of the results of actual tests such as those described by the author, with those of an analysis of the sort I have described would reveal the presence of leaks, obstructions or needed reinforcements in the system such as would not readily be discovered in other ways.

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Fabricated Steel Ring Flanges for Water Pipe Service for Low Pressures and Low Temperatures

By H. O. Hill, W. W. Lewis and H. J. Easter

THE only type of pipe flange for steel water pipe that has any recognized standing in the industry is the forged steel flange in sizes up to and including 24-in. diameter. These have been "designed" or copied directly from the cast-iron pipe flanges and have exactly the same thicknesses and other dimensions, except they are rated for 25 psi. higher pressure.

There are no recognized standards for steel pipe flanges larger than 24-in. diameter. Forged steel flanges larger than 24-in. diameter are manufactured but the dimensions vary from those used for cast-iron flanges to thinner sections with higher pressure ratings but all lacking any degree of standardization.

Water pipe service requires flanges to operate in the range of 75 psi. to 150 psi. at temperatures below 200°F. There is thus a great need for a recognized design of standard steel flanges for operation at the low pressures and temperatures required for water service. Such flanges can readily be made from plates or slabs at a much lower cost than those made from forgings. Submitted herewith is a design study covering a series of plate ring flanges suitable for water service.

It is the purpose of this paper to present designs for a series of flanges which will be suitable and economical for water distribution lines which function at pressures up to 150 psi. and temperatures not exceeding 200°F.

A great many flanges are being used on water pipe, some being used for connections between pipe and valves, and some engineers specify that certain critical portions of their lines be flanged.

Since there are no recognized standard steel flanges suitable for this class of service the pipe fabricators have been compelled to resort to one of two choices:

(1) Furnish flanges to conform with American Standards Association specifications—Steel Pipe Flanges and Flanged Fittings A.S.A. (B16e—1939), or (2) furnish flanges of their own design.

From the water works viewpoint there are three main objections to the A.S.A. standard flanges, namely:

(1) They were designed for pressure-temperature ratios far in excess of those encountered in the water works field, consequently they are not economical.

A paper presented on June 24, 1942, at the Chicago Conference by H. O. Hill, Asst. Chief Engr., with the co-operation of W. W. Lewis and H. J. Easter, Engrs., Bethlehem Steel Co., Bethlehem, Pa.

(2) The A.S.A. standard steel flanges are limited in size to 24-in. diameter. Water distribution lines range in size up to 96-in. diameter and a few have gone as high as 120-in. diameter. When A.S.A. flanges are specified for sizes over 24-in. diameter, it becomes necessary to resort to the A.S.A. cast-iron standards for dimensions.

(3) There are no A.S.A. standard steel flanges for pressures of 150 psi. or under and temperatures not exceeding 200°F. This pressure-temperature ratio is about the maximum ever encountered in water lines. Practically all water distribution lines are buried and probably never have temperatures exceeding 60° to 70°F.

The 150-lb. A.S.A. Steel Flanges (B16e—1939) were designed for operating pressures of 150 psi. when subjected to a temperature of 500°F. On a supplementary pressure-temperature ratio table these same flanges have a pressure rating of 230 psi. when operating at 100°F. and 220 psi. at 150°F.

It is not economical to use 230-lb. flanges for services varying from probably 25 psi. up to 150 psi. It surely cannot be considered sound engineering since they do not furnish a balanced design for the complete installation. Furthermore it is a needless waste of material, which is a serious problem now, and should not exist at any time.

Flange Design

During the past 12 or 14 yr. there have been considerable data published on the design of both ring and hub type flanges. The publishing of these data has brought forth enlightening discussions out of which has evolved a fairly simple method of designing loose ring flanges and a complicated but workable method of designing hub flanges. The American Society of Mechanical Engineers and the American Petroleum Institute—American Society of Mechanical Engineers codes have adopted standard procedures for flange design, both of which are outgrowths of the aforementioned papers and discussion. Based on these same methods of design the A.S.A. has set up a table of standard flanges for pipe up to and including 24-in. However, the available published data and the various codes apparently have overlooked one important phase of flange design, i.e., ring flanges attached or "fixed" to the pipe shell.

Ring flanges, as interpreted by the codes and by most publications, have been considered as loose flanges or as flanges for the Van Stone type of joint. Fixed or integral flanges usually have been treated and designed as hub flanges, made integral with the pipe shell by butt welding. Other factors which appear to have been adhered to are high temperature, and, for most of the published data, high pressures.

For these designs we have adopted the ring flange, or a flange without a hub, attached to the pipe by fillet welds and which is to function at pressures of 75 and 150 psi. (Fig. 1) and temperatures not exceeding 200°F. This type of flange has been selected for several reasons:

(1) It has been used extensively over a period of years and has given excellent service.

(2) It is economical.

(3) It can be fabricated by means of common fabricating tools such as flame cutting, machining and welding.

(4) It may be cut from a solid plate or slab or made from several bars formed or cut and welded together to

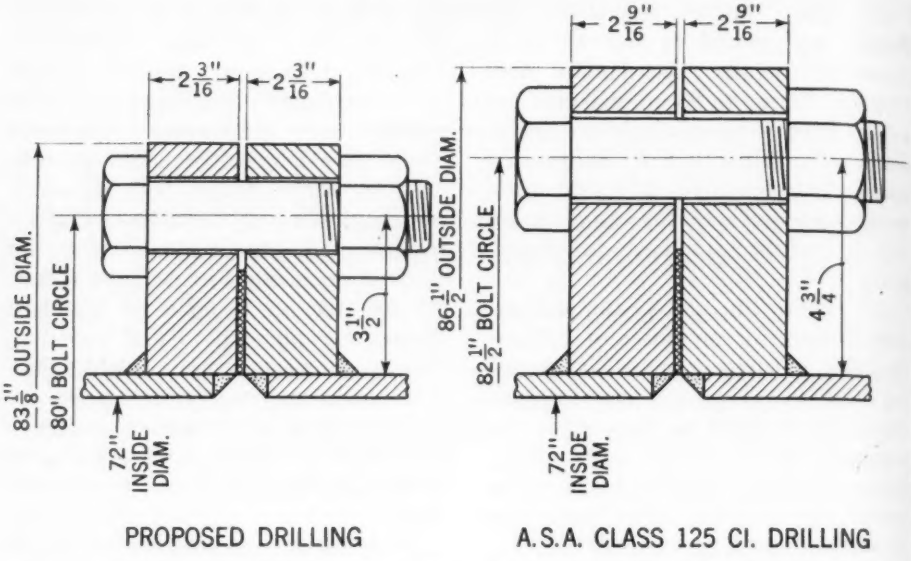


FIG. 1. Comparative Size of 72 In. Flanges 150 Pounds Per Sq. In. Working Pressure.

form a complete ring thus eliminating waste from centers on large diameter pipe. It is proposed to set up designs of a series of standard flanges, for water pipe, ranging in size from 4- to 120-in. diameter, and embracing those sizes most commonly used.

In order to design flanges a number of factors must be established, and for standard flanges, these same factors must be standardized. These items are as follows:

1. Unit stress in pipe wall
2. Unit stress in flange
3. Unit stress in bolts
4. Type and material of gasket
5. Gasket load
6. Bolt load
7. Bolt size
8. Bolt circle diameter
9. Spacing of bolts
10. Width of gasket
11. Inside diameter of flange
12. Outside diameter of flange

With the above information the design of a flange becomes a relatively simple matter.

Unit Stress in Flange and Pipe

For uniformity of the design the stress in the pipe wall and the stress in the flange should have the same limiting value. The value assigned in the following series of flanges is 13,500 psi.

Unit Stress in Bolts

The unit stress in the bolts may have any assigned value depending upon the physical properties of the bolt material but in the present case the allowable stress has been set at 13,500 psi.

Type and Material of Gasket

Gaskets may be of innumerable types and materials and the suitability of one type over another is still causing considerable controversy. Most of the published information on gaskets (8,

9, 10, 11, 13, 14) deals with high-temperature and high-pressure service.

Waters, Wesstrom and Williams (8) have the following comments:

Gaskets are of many types so that no attempt will be made to classify them all, but there are a few commonly used types that are easily described. On low-pressure, low-temperature work it is common practice to use a full-face gasket extending to the outside diameter of the flange and with the bolt holes cut out. Such gaskets are usually soft and require a low unit compression to keep them tight. It is rarely that a contact-pressure ratio of more than one or two is required.

Another usual type is a wide-ring gasket extending from the inside diameter of the joint to some point within the line of bolts. If this type of gasket were made of a rubber composition or something similar, it would be expected that a small gasket compression would hold the joint tight, but if the gasket material were a hard substance like asbestos composition, a higher unit compression would be required. If such a wide-ring type of gasket were made of hard metal the unit compression would need to be still higher. Such gaskets are usually applied to a flat or raised face on the flange and, generally speaking, their use is limited to 300 psi. and 750°F.

The second type mentioned above, i.e., wide-ring gasket extending from the inside diameter of the joint to some point within the line of bolts, will be adopted here, using a cloth-inserted rubber as the material. For this material, we will assume a yield point of 750 psi. and this value will be used hereinafter.

Gasket Load

The subject of gasket load is treated by Waters, Wesstrom and Williams (8) from which the following is quoted:

A well-designed flanged joint must put sufficient pressure on the gasket to hold the joint tight at all times without overstressing the flange and bolting material. The pressure is applied to the gasket by means of the bolting. The further discussion may be easier to follow if we first examine the conditions that exist in bolted connections under service conditions. When these bolts are initially set up the internal fluid pressure is not present and the total bolt load is available to seat the gasket and insure full bearing and contact over its entire surface. The pressure is then applied and the force compressing the gasket is diminished to a greater or less extent, depending on the relative elasticity of the bolting and the gasket. This residual force required to keep the joint tight is the gasket force (compression).

The unit gasket compression is, of course, expressed in pounds per square inch, and is most commonly designated in terms of a multiple of the internal working pressure of the vessel, which multiple is known as the contact-pressure ratio. In other words, the contact-pressure ratio is the ratio of the unit contact (gasket pressure) to the unit internal pressure.

For the cloth-inserted rubber wide-face ring gasket selected here, a contact-pressure ratio of $\frac{3}{4}$ or 0.75 has been selected as suitable and adequate.

Bolt Load

The bolt load is determined as follows:

The minimum bolt load, W, is determined from the gasket yielding load or from the gasket pressure load plus the hydrostatic end load (whichever is greater).

The hydrostatic end force is the product of the internal pressure and the area bounded by the diameter of the pipe.

The gasket pressure load is determined by multiplying the internal pressure by the contact-pressure ratio and then multiplying this value by the annular area of the gasket or compression surface.

The gasket yielding load is determined as follows:

Gasket yielding load $= \pi\, n\, a\, r$

Where n = effective gasket yielding width = $\frac{1}{2}$ width of gasket for flat gasket

a = mean diameter of gasket

r = yield point of gasket material

Bolt Size

The size of bolts will be affected by spacing limitations as well as load requirements. In general, small bolts should be avoided due to the ease with which they may be broken by careless workmen. No hard and fast rule can here be set down for size of bolts. In the present case their size has been made to conform more or less to current practice as well as to satisfy load and spacing requirements.

Bolt Circle Diameter

In general, the bolt circle should be maintained at a minimum value.

In the present case, the bolt circle has been determined as follows:

Diameter of bolt circle, b = inside diameter of pipe $+ 4 \times$ (max. t) $+ 2 \times$ (constant for wrench clearance).

The basis for the above is as follows:

It will be noted that in Table A there are two thicknesses of pipe. The first is the actual design thickness and the second is a value listed as maximum value for bolt circle calculation. The reason for this latter thickness is that water pipe is often, for practical reasons, made thicker than required by design stresses. By using the maximum value which is likely to occur for the given pressure requirements, the bolt circle is moved out to a maximum value, thus increasing the bolt load, W, and providing a factor of a safety where the thickness actually used is that dictated by design requirements. It will also be noted from Fig. 2 that a fillet weld is provided at the junction of flange and pipe of size equal to the thickness of the pipe; therefore, for the bolt circle it is necessary to add four thicknesses to the inside diameter of the pipe in addition to a constant for wrench clearance which is dependent upon the size of bolt used. The value of this constant is given below.

Values of Constants for Bolts

Diameter of Bolt	Constant for Wrench Clearance	Width of Nut Across Corners
$\frac{1}{2}$	$1\frac{3}{16}$	1.01
$\frac{5}{8}$	$1\frac{5}{16}$	1.23
$\frac{3}{4}$	$1\frac{1}{8}$	1.44
$\frac{7}{8}$	$1\frac{1}{4}$	1.66
1	$1\frac{3}{8}$	1.88
$1\frac{1}{8}$	$1\frac{1}{2}$	2.09
$1\frac{1}{4}$	$1\frac{3}{4}$	2.31
$1\frac{3}{8}$	$1\frac{7}{8}$	2.53
$1\frac{1}{2}$	2	2.74
$1\frac{5}{8}$	$2\frac{1}{4}$	2.96

Spacing of Bolts

The Waters-Taylor A.S.M.E. paper (1) recommends a bolt spacing of at least $2\frac{1}{4}$ bolt diameters between centers to avoid high-stress concentration.

The maximum bolt spacing to prevent gasket blow-out or leaks is controversial. In the present paper a maximum spacing of 5 bolt diameters has been adhered to with two or three exceptions and these exceptions, in most cases, conform to spacings given for identical size A.S.A. flanges.

Width of Gasket

The outside diameter of the gasket has been made something less than the diameter of the bolt circle at the inner edge of the bolts to insure ease of assembly and prevent the gasket from obstructing the bolt holes. The value

of these constants so chosen are shown in Fig. 2.

Inside Diameter of Flange

For the present series of flanges the inside diameter of the flange has been taken as the outside diameter of the pipe using the minimum thickness of pipe. This gives the maximum bolt load and therefore provides additional strength if thicker pipes are used.

Outside Diameter of Flanges

The outside diameter of the flange is determined in accordance with the method as given by Walters, Wesstrom and Williams (8) which is as follows:

"The outside diameter of the flange must be large enough to seat the bolt with some manufacturing tolerance to spare. A safe rule to follow is:

Outside diameter of flange = (Bolt circle) + (Width of nut across corners) + $\frac{3}{8}$ in.

The $\frac{3}{8}$ in. is made up of the following factors:

Oversize of bolt hole, $\frac{1}{8}$ in.; outside diameter of flange should be $\frac{1}{8}$ in. larger in diameter than the swing of the nuts to allow full seating; manufacturing tolerance, $\frac{1}{8}$ in.; a total of $\frac{3}{8}$ in."

Flange Face

A flat face flange has been adopted for this low-pressure and low-temperature service because such have proven to be satisfactory in years of service. Raised face flanges would induce increased bending in the flanges and pipe shell and would require thicker sections than are necessary for this class of service.

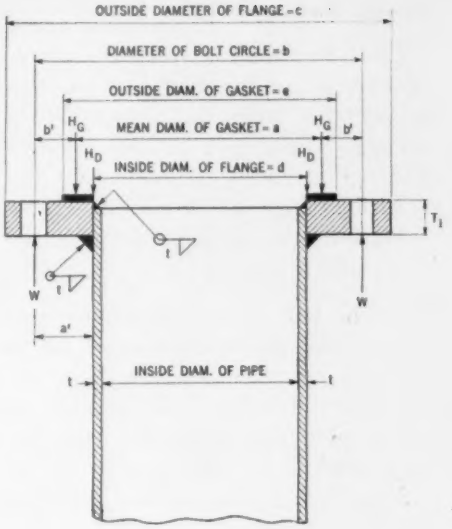


FIG. 2

Nomenclature:

t = Thickness of pipe wall = $\frac{p \times \text{id.}}{2 \times 5}$.

p = Internal working pressure in pounds per square inch.

id. = Inside diameter of pipe in inches.

s = Allowable unit stress in pounds per square inch = 13,500.

b = Diameter of bolts circle = inside diameter of pipe + 4 × (max. t) + 2 × (constant for wrench clearance).

e = Outside diameter of gasket = b − (diameter of bolt + $\frac{1}{2}$ in. for pipe up to 24-in. id., $\frac{3}{4}$ in. for pipe from 24- to 48-in. id. and 1 in. for pipe over 48-in. id.).

a = Mean diameter of gasket = $\frac{e+d}{2}$.

d = Inside diameter of flange and gasket = outside diameter of pipe.

c = Outside diameter of flange = b + width of nut across corner + $\frac{3}{8}$ in.

w = Total bolt load = hydrostatic end force $\left[\frac{\pi d^2}{4} p\right]$ + gasket pressure $\left[\frac{\pi}{4}(e^2 - d^2) \times p \times 0.75\right]$ or gasket yielding load $\left[\pi a \times 750 \times \frac{1}{2}\left(\frac{e-d}{2}\right)\right]$ whichever is the greater.

a' = Lever arm from hydrostatic and pressure (H_D) to bolt circle.

b' = Lever arm from gasket pressure (H_G) and gasket yield load H_{GY} to bolt circle.

T_1 = Thickness of flange.

n = Width of gasket = $\frac{e-d}{2}$.

Design Basis

The flange shall be treated as a cantilever beam made integral, at its inner peripherary, with the pipe wall by welding. To determine the thickness of flange required, a unit width of 1 in. of the flange has been used.

The following assumptions have been made:

1. The bolt load is distributed uniformly over the circumference of the bolt circle.
2. The allowable unit stresses for the the pipe wall, flange and bolts shall not exceed 13,500 psi.
3. A cloth-inserted rubber ring gasket shall be used.
4. A contact-pressure ratio of ¾ or 0.75 has been selected as suitable and adequate for the cloth-inserted rubber gasket.
5. A gasket yield point of 750 psi.

The total hydrostatic end force (H_D) is equal to the product of the internal pressure and the area bounded by the diameter of the pipe:

$$H_D = \frac{\pi d^2 p}{4}$$

and the hydrostatic end force on a unit width of 1 in. of the flange will then be

$$H_D \text{ per lin.in.} = \frac{\pi d^2 p}{4} \times \frac{1}{\pi d} = \frac{dp}{4} \quad (1)$$

The total gasket pressure force (H_G) is the product of the internal pressure, the contact-pressure ratio and the area of the gasket or compression surface.

$$H_G = 0.75\pi p \left(\frac{e^2 - d^2}{4}\right) \quad (\textit{See} \text{ Fig. 2.})$$

and the gasket pressure force for a unit width of 1 in. of the flange will then be

$$H_G \text{ per lin.in.} = 0.75\pi p \left(\frac{e^2 - d^2}{4}\right) \div \pi \left(\frac{e + d}{2}\right)$$

$$= 0.75p \left(\frac{e - d}{2}\right) = 0.75pn \quad (2)$$

where $n = \left(\frac{e - d}{2}\right)$

The total gasket yielding force (HG_Y) is the product of one-half the width of the gasket, the mean circumference of the gasket and the gasket yield point

$$HG_Y = 750\pi a \times \frac{1}{2}\left(\frac{e - d}{2}\right) = \frac{375\pi}{4}(e^2 - d^2)$$

and the gasket yielding force for a unit width of 1 in. of the flange will then be

$$HG_Y \text{ per lin.in.} = \frac{375\pi}{4}(e^2 - d^2) \div \pi \left(\frac{e + d}{2}\right)$$

$$= 375\left(\frac{e - d}{2}\right) = 375n \quad (3)$$

The total bolt load (W) is equal to the gasket yielding force or the sum of the gasket pressure force plus the hydrostatic end force (whichever is the greater)

$$W = HG_Y \text{ or } HG + HD \text{ (whichever is the greater)}$$

$$= \frac{375\pi}{4}(e^2 - d^2)$$

or

$$\frac{\pi p}{4}[0.75(e^2 - d^2) + d^2]$$

(whichever is the greater)

MOMENTS:

Due to hydrostatic end force per lineal inch $= M_{HD} = \frac{dp}{4} \times a'$

Due to gasket pressure force per lineal inch $= M_{HG} = 0.75\,pn \times b'$ and total moment due to hydrostatic end force and gasket pressure force per lineal inch $= M_{HD} + M_{HG}$

$$= \frac{p}{4}(da' + 3\,nb') \quad (4)$$

Due to gasket yielding force per lineal inch $= M_{HGY} = 375\,n \times b'$ (5)

Section Modulus of flange section per lineal inch

$$S = \frac{M}{13500} \text{ also } S = \frac{T_1^2}{6}$$

$$\therefore \quad \frac{T_1^2}{6} = \frac{M}{13500} \quad \text{and} \quad T_1^2 = \frac{6M}{13500}$$

M = Eq. (4) or Eq. (5) whichever is the greater

$$\therefore \quad T_1^2 = \frac{6(M_{HD} + M_{HG})}{13500}$$

$$= \frac{p(da' + 3nb')}{9000} \quad (6)$$

or

$$T_1^2 = \frac{6M_{HGY}}{13500} = \frac{nb'}{6} \quad (7)$$

whichever is the greater.

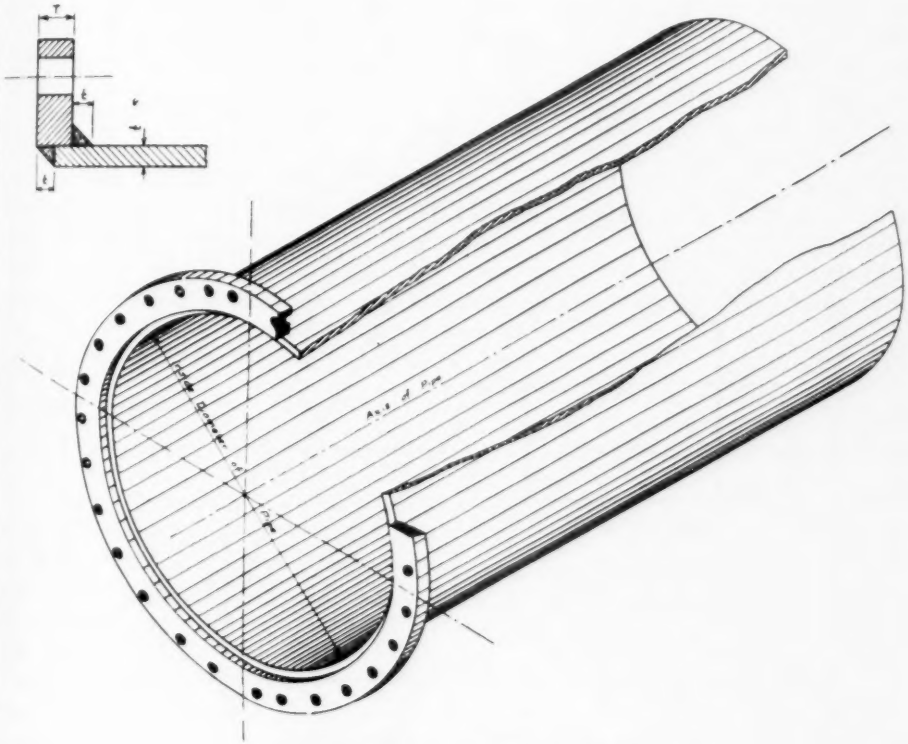


FIG. 3. Attachment of Flange to Pipe.

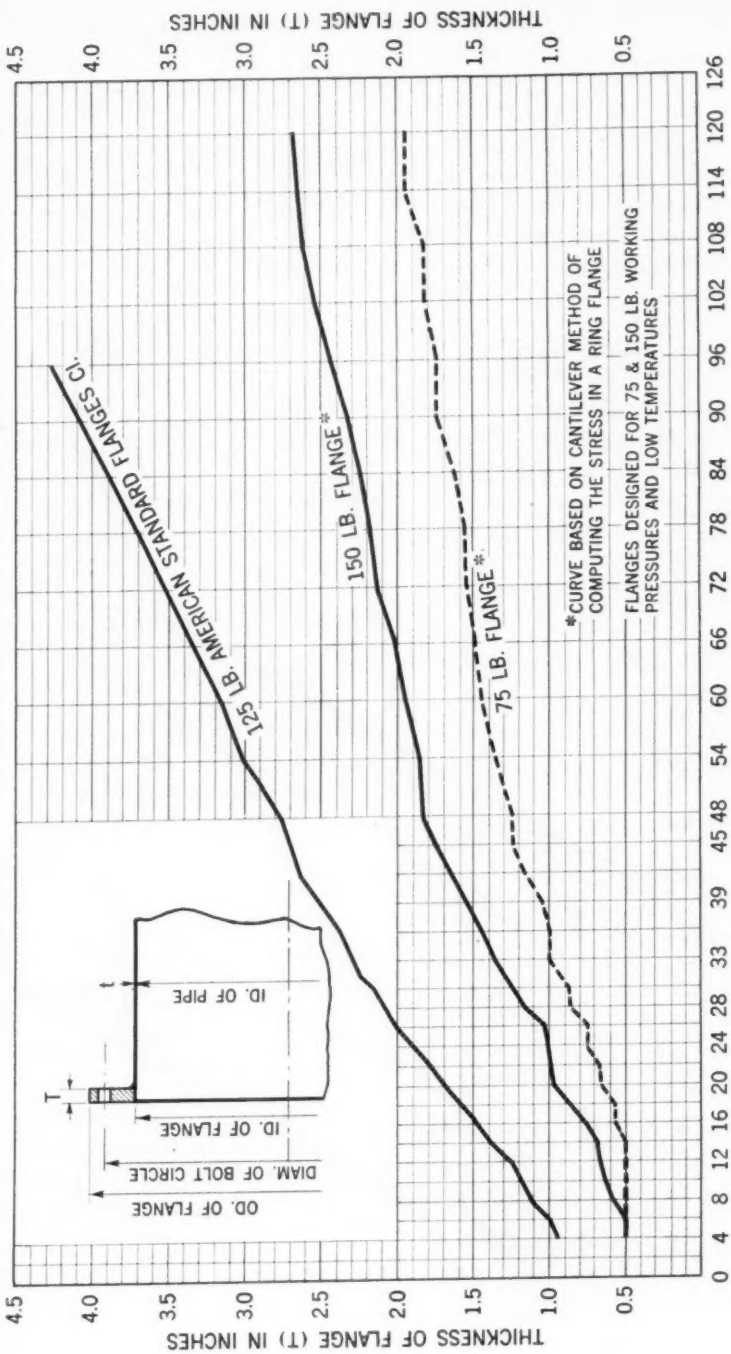

THICKNESS OF FLANGE (T) IN INCHES
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
125 LB. AMERICAN STANDARD FLANGES CI.
150 LB. FLANGE*
75 LB. FLANGE*
*CURVE BASED ON CANTILEVER METHOD OF COMPUTING THE STRESS IN A RING FLANGE
FLANGES DESIGNED FOR 75 & 150 LB. WORKING PRESSURES AND LOW TEMPERATURES
INSIDE DIAMETER OF PIPE IN INCHES
0 4 8 12 16 20 24 28 33 39 45 48 54 60 66 72 78 84 90 96 102 108 114 120 126
T
t
I.D. OF PIPE
I.D. OF FLANGE
DIAM. OF BOLT CIRCLE
O.D. OF FLANGE

FIG. 4. Ring Flanges for Low Pressure—Low Temperature Service New Drilling Templates.

Performance Satisfactory

The foregoing "factors" in flange design as used in this paper have been summaried in Figs. 2 and 3 and Table A. The design of a series of flanges ranging in size from 4 to 120 in. by the "Cantilever Analogy," using working pressures of 75 and 150 psi.; maximum temperature of 200°F.; unit stresses in pipe, flange and bolts of 13,500 psi.; cloth-inserted rubber flat ring gaskets and maximum bolt spacings of 5 diameters is summarized in Tables B and C and Fig. 4 for ready reference.

It is believed that this series of flanges will perform satisfactorily for the service condition stipulated and that they will satisfy a long felt need for a series of flanges for steel pipe for water or oil transmission.

Criticism of the flanges in Tables B and C may be advanced on the basis of the following:

The flanges in Tables B and C do not have drilling templates which will match the drilling of any existing flanges or fittings. This means that new pipelines tying into existing lines or fittings must have special flanges for these particular connections, unless the valve and fitting manufacturers would adopt the new drilling templates.

Solution Offered

The following is offered as a solution to this problem: In Tables D and E are a series of flanges which were designed by the same method as those in Tables B and C, but the drilling templates are those adopted as American Standard for Cast-Iron Pipe for 125 psi. Working Saturated Steam Pressure (American Standard Cast-Iron Pipe Flanges and Flanged Fittings-Class 125 A.S.A. B16a—1939). The bolt circle diameters, size of bolts, number of bolts and spacing of bolts all conform to the above-mentioned standard. The other dimensions were determined in accordance with the methods used in Tables B and C and the "Cantilever Analogy" was used as the design formula.

Saving Plate Material

It will be noted in Table F, which compares values of Tables B with D, showing 75-lb. flanges and C with E, showing 150-lb. flanges, that the proposed new drilling effects a very considerable saving in plate material and bolts and therefore appreciable saving in costs, with no loss in strength.

Therefore, for a flanged pipeline, it would seem economical to use two different types of flanges, i.e., for new flanged connections use the flanges in Table B or C and for connection to existing flanges and fittings use the flanges in Table D or E until such time as consumer demand would warrant a change-over of drilling templates by valve and fitting manufacturers.

Table G gives a comparison of the dimensions of the proposed flanges, also A.S.A. standard cast-iron and steel flanges.

Reference

1. Everett O. Waters & J. Hall Taylor. The Strength of Pipe Flanges. Mech. Eng., **49**: 531 (1927).
2. S. Timonshenko *Discussion.* Methods of Determining the Strength of Pipe Flanges. Mech. Eng., **49**: 1340 (1927).
3. A. M. Wahl & G. Lobo, Jr. Stresses and Deflections in Flat Circular Plates With Central Holes. Trans. A.S.M.E., **52**: 29 (1930).
4. E. O. Holmberg & Karl Axelson. Analysis of Stresses in Circular Plates and Rings. Trans. A.S.M.E., **54**: 13 (1932).

5. R. J. Roark. Stress and Deflections in Flat Plates. Product Eng., **7**: 252–283 (1937).
6. T. McLean Jasper, H. Gregersen & A. M. Zoellneer. Strength and Design of Covers and Flanges for Pressure Vessels and Piping. Heating, Piping and Air Condg., **8**: 605, 672 (1936); **9**: 43, 109, 174, 178, 243, 311 (1937).
7. Everett O. Waters, D. B. Wesstrom, D. B. Rossheim & F. S. G. Williams, Formulas for Stresses in Bolted Flanged Connections. Trans. A.S.M.E., **59**: 161 (1937).
8. Everett O. Waters, D. B. Wesstrom & F. S. G. Williams. Design of Bolted Flanged Connections. Mech. Eng., **56**: 736, 763 (1934).
9. C. O. Sandstrom. Bolts and Flanges for Tanks and Heat Exchangers. Chem. & Met. Eng., **40**: 67 (1933).
10. E. C. Petrie. Flanged Piping Joints, Methods for Applying and Determining Bolt Stresses. Heating, Piping and Air Condg., **8**: 303 (1936).
11. J. D. Mattimore, N. O. Smith-Peterson & H. C. Bell. Design of Flanged Joints for Valve Bonnets. Trans. A.S.M.E., **60**: 297 (1938).
12. D. B. Rossheim, E. H. Gebhardt & H. G. Oliver. Tests of Heat-Exchanger Flanges. Trans. A.S.M.E., **60**: 305 (1938).
13. E. C. Petrie. The Ring Joint, Its Relative Merit and Application. Heating, Piping and Air Condg., **9**: 213 (1937).
14. *Modern Flange Design.* Taylor Forge and Pipe Works, Chicago, Ill., (1938).

The American Standards frequently referred to by the authors of the above paper are the following:

Cast-Iron Pipe Flanges and Flanged Fittings, Class 125 (B16a-1939) ... $0.60
Cast-Iron Pipe Flanges and Flanged Fittings, for Maximum Working Saturated Steam Pressure of 25 Lb. per Sq.In. (Gage) (B16b2-1931) $0.40
Steel Pipe Flanges and Flanged Fittings of 150, 300, 400, 600, 900, 1500 2500 Lb. per Sq.In. (Gage), at Temperatures Ranging From 100 to 1000 F., Including Welding Neck Flanges, Ring Joints, and Bolt Lengths (B16e-1939) $1.25

The above standards may be obtained from the American Standards Association, 29 West 39th Street, New York, N.Y.

TABLE A

Maximum and Minimum Thicknesses of Pipe Shell for 75 and 150 Psi. Working Pressure for Bolt Circle Calculations

1	2	3	4	5	6	7
Inside Diameter of Pipe, Inches	Thickness of Pipe, t; Inches			Thickness for Pipe, t: Inches		
	Pressure = 75 lb. Unit Pressure = 13,500 $t = \frac{75 \times \text{id.}}{2 \times 13{,}500}$		Maximum Value for Bolt Circle Calculation	Pressure = 150 lb. Unit Pressure = 13,500 $t = \frac{150 \times \text{id.}}{2 \times 13{,}500}$		Maximum Value for Bolt Circle Calculation
	Decimal	Fraction		Decimal	Fraction	
4	0.01	1/16	1/4	0.02	1/16	1/4
6	0.02	1/16	5/16	0.03	1/16	5/16
8	0.02	1/16	3/8	0.04	1/16	3/8
10	0.03	1/16	3/8	0.05	1/16	3/8
12	0.03	1/16	3/8	0.07	1/16	3/8
14	0.04	1/16	3/8	0.08	1/8	3/8
16	0.04	1/16	3/8	0.09	1/8	3/8
18	0.05	1/16	3/8	0 10	1/8	3/8
20	0.06	1/16	1/2	0.11	1/8	1/2
22	0.06	1/16	1/2	0.12	1/8	1/2
24	0.07	1/16	1/2	0.13	1/8	1/2
26	0.07	1/16	1/2	0.14	1/8	1/2
28	0.08	1/8	3/4	0.16	3/16	3/4
30	0.08	1/8	3/4	0.17	3/16	3/4
33	0.09	1/8	3/4	0.18	3/16	3/4
36	0.10	1/8	3/4	0.20	3/16	3/4
39	0.11	1/8	3/4	0.22	1/4	3/4
42	0.12	1/8	1	0.23	1/4	1
45	0.12	1/8	1	0.25	1/4	1
48	0.13	1/8	1	0.27	1/4	1
54	0.15	3/16	1	0.30	5/16	1
60	0.17	3/16	1	0.33	5/16	1
66	0.18	3/16	1	0.37	3/8	1
72	0.20	3/16	1	0.40	3/8	1
78	0.22	1/4	1	0.43	7/16	1
84	0.23	1/4	1	0.47	1/2	1
90	0.25	1/4	1	0.50	1/2	1
96	0.27	1/4	1	0.53	1/2	1
102	0.28	5/16	1	0.57	9/16	1
108	0.30	5/16	1	0.60	5/8	1
114	0.32	5/16	1	0.63	5/8	1
120	0.33	5/16	1	0.67	11/16	1

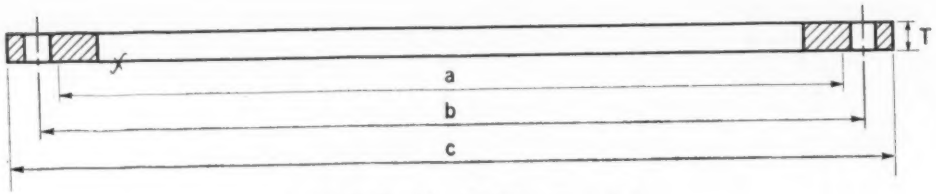


TABLE B—New Drilling Templates

Ring Flanges for 75 Psi. Working Pressure
(Temperature Not to Exceed 200° F.)

1	2	3	4	5	6	7	8	9	10	11	12
Diameter of Pipe	Outside Diameter of Flange *c*	Thickness of Flange *T*		Outside Diameter of Gasket *e*	Number of Bolts	Diameter of Bolts	Diameter of Bolt Holes	Diameter of Bolt Circle *b*	Spacing of Bolts in Bolt Diameters	Approximate Net Weight of Flange—lb.	Diameter of Pipe
		Actual Design Value	Actual Thickness Used								
4	8	0.243		5½	8			6¾	5.20	5	4
6	10¾	0.317		8	8			9¼	5.73	7	6
8	13	0.373		10¼	8			11½	4.77	10	8
10	15⅝	0.435		12½	12			13¾	4.80	13	10
12	17⅞	0.469		14¾	12			15¾	4.12	15	12
14	20	0.518		16¾	16		1	18	4.04	24	14
16	22¼	0.549		18¾	16		1	20	4.49	29	16
18	24½	0.609		20¾	16	1	1¼	22¼	4.37	36	18
20	27	0.669		23¼	16	1	1¼	24¼	4.36	47	20
22	29½	0.718		25¾	16	1¼	1¼	27	4.71	60	22
24	31¾	0.746		27¾	16	1¼	1¼	29	5.06	65	24
26	33¾	0.774		29¾	20	1¼	1¼	31	4.33	75	26
28	36¼	0.877		32¼	20	1¼	1¼	34	4.75	100	28
30	38¾	0.904		33¾	24	1¼	1¼	36	4.19	118	30
33	42¼	0.988	1	37¼	24	1¼	1¼	39¼	4.14	142	33
36	45¼	1.026	1 1/16	40¼	24	1¼	1¼	42¼	4.45	164	36
39	48¼	1.064	1 1/16	43¼	24	1¼	1¼	45¼	4.76	177	39
42	52¼	1.195	1 3/16	47¼	28	1¼	1¼	49¼	4.44	238	42
45	55¼	1.232	1¼	50¼	28	1¼	1¼	52¼	4.71	267	45
48	58¼	1.269	1¼	53¼	32	1¼	1¼	55¼	4.36	282	48
54	64¾	1.350	1¾	59¾	32	1¼	1¼	61¾	4.41	364	54
60	70¾	1.417	1 7/16	65¾	32	1¼	1¼	67¾	4.84	421	60
66	76¾	1.480	1½	71¾	36	1¼	1¼	73¾	4.68	479	66
72	82¾	1.542	1 9/16	77¾	40	1¼	1¼	79¾	4.56	540	72
78	88¾	1.587	1⅝	83¾	40	1½	1½	85¾	4.90	608	78
84	94¾	1.643	1 11/16	89¾	44	1½	1½	91¾	4.76	675	84
90	101¼	1.728	1¾	95¾	44	1½	1½	98	4.66	783	90
96	107¼	1.781	1 13/16	101¾	44	1½	1½	104	4.95	865	96
102	113¼	1.818	1 13/16	107¾	48	1½	1½	110	4.80	914	102
108	119¼	1.868	1⅞	113¾	52	1½	1½	116	4.67	996	108
114	125¼	1.917	1 15/16	119¾	52	1½	1½	122	4.91	1087	114
120	131¼	1.964	2	125¾	60	1½	1½	128	4.47	1172	120

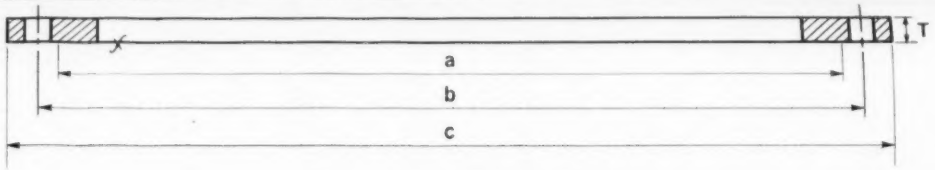


TABLE C—New Drilling Templates

Ring Flanges for 150 Psi. Working Pressure
(Temperature Not to Exceed 200° F.)

1	2	3	4	5	6	7	8	9	10	11	12
Diameter of Pipe	Outside Diameter of Flange *c*	Thickness of Flange *T*		Outside Diameter of Gasket *e*	Number of Bolts	Diameter of Bolts	Diameter of Bolt Holes	Diameter of Bolt Circle *b*	Spacing of Bolts in Bolt Diameters	Approximate Net Weight of Flange—lb.	Diameter of Pipe
		Actual Design Value	Actual Thickness Used								
4	8	0.345	7/16	5 5/8	8	5/8	3/4	6 5/8	5.20	5	4
6	10 1/2	0.449	7/16	8	8	3/4	7/8	9 1/4	5.73	7	6
8	13 1/2	0.564	9/16	10 1/2	8	7/8	1	11 3/4	6.15	13	8
10	15 7/8	0.615	5/8	12 1/2	12	7/8	1	13 3/4	4.80	17	10
12	18	0.688	11/16	14 3/4	12	7/8	1	16	4.80	23	12
14	20	0.722	3/4	16 1/2	16	7/8	1	18	4.04	31	14
16	22 1/2	0.792	13/16	18 3/4	16	1	1 1/8	20 1/4	3.98	42	16
18	24 1/2	0.833	13/16	20 3/4	16	1	1 1/8	22 1/4	4.37	46	18
20	27	0.962	1	23	16	1 1/8	1 1/4	25	4.36	74	20
22	29 1/4	1.003	1	25 1/4	16	1 1/4	1 1/4	27	4.71	80	22
24	31 1/2	1.042	1 1/16	27 1/4	16	1 1/4	1 1/4	29	5.06	92	24
26	33 1/2	1.076	1 1/16	29 1/4	20	1 1/4	1 1/4	31	4.33	98	26
28	36 1/2	1.228	1 1/4	32 1/4	20	1 1/4	1 1/4	34	4.75	144	28
30	38 1/2	1.260	1 1/4	33 1/4	20	1 1/4	1 1/4	36	4.52	157	30
33	42 1/4	1.380	1 3/8	37 1/4	20	1 1/4	1 1/4	39 1/2	4.96	201	33
36	45 1/4	1.438	1 7/16	40 1/4	24	1 1/4	1 1/4	42 1/2	4.45	226	36
39	48 1/4	1.475	1 1/2	43 1/4	24	1 1/4	1 1/4	45 1/2	4.76	254	39
42	52 1/4	1.662	1 11/16	47 1/4	28	1 1/4	1 1/4	49 1/2	4.44	343	42
45	55 1/4	1.746	1 3/4	50 1/4	28	1 1/4	1 1/4	52 3/4	4.31	392	45
48	58 1/4	1.798	1 13/16	53 1/4	28	1 1/4	1 1/4	55 3/4	4.55	431	48
54	64 1/4	1.878	1 7/8	59 1/4	36	1 1/4	1 1/4	61 3/4	3.92	492	54
60	70 1/2	1.970	2	65 1/4	40	1 1/4	1 1/4	67 3/4	3.87	578	60
66	76 1/2	2.040	2 1/16	71 1/4	48	1 1/4	1 1/4	73 3/4	3.51	646	66
72	83 1/2	2.170	2 3/16	77 1/4	48	1 1/4	1 1/4	80	3.49	778	72
78	89 1/2	2.230	2 1/4	83 1/4	52	1 1/4	1 1/4	86	3.46	862	78
84	95 1/2	2.290	2 5/16	89 1/4	60	1 1/4	1 1/4	92	3.21	943	84
90	101 1/2	2.360	2 3/8	95 1/4	68	1 1/4	1 1/4	98	3.02	1029	90
96	107 1/2	2.440	2 7/16	101 1/4	76	1 1/4	1 1/4	104	2.87	1117	96
102	113 1/2	2.530	2 1/2	107 1/4	72	1 1/2	1 1/2	110 1/4	2.96	1303	102
108	119 1/2	2.580	2 5/8	113 1/4	80	1 1/2	1 1/2	116 1/4	2.81	1401	108
114	125 1/2	2.640	2 5/8	119 1/4	88	1 1/2	1 1/2	122 1/4	2.69	1470	114
120	131 1/2	2.680	2 11/16	125 1/4	100	1 1/2	1 1/2	128 1/4	2.48	1566	120

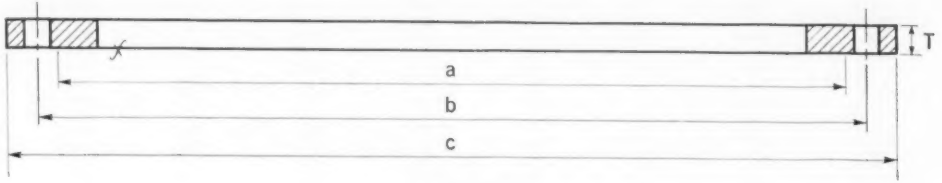


TABLE D

Ring Flanges for 75 Psi. Working Pressure
(Temperature Not to Exceed 200°F.)
Drilling Same as American Standard for Cast-Iron Pipe for 125 psi. Working Saturated Steam Pressure (B16a-1939)

1	2	3	4	5	6	7	8	9	10	11	12
Diameter of Pipe	Outside Diameter of Flange *c*	Thickness of Flange *T*		Outside Diameter of Gasket *e*	Number of Bolts	Diameter of Bolts	Diameter of Bolt Holes	Diameter of Bolt Circle *b*	Spacing of Bolts in Bolt Diameters	Approximate Net Weight of Flange—lb.	Diameter of Pipe
		Actual Design Value	Actual Thickness Used								
4	9	0.297	$\frac{1}{2}$	$6\frac{3}{16}$	8	$\frac{5}{8}$	$\frac{3}{4}$	$7\frac{1}{2}$	4.71	6	4
5	10	0.321	$\frac{1}{2}$	$7\frac{5}{16}$	8	$\frac{3}{4}$	$\frac{7}{8}$	$8\frac{1}{2}$	4.45	7	5
6	11	0.345	$\frac{1}{2}$	$8\frac{1}{2}$	8	$\frac{3}{4}$	$\frac{7}{8}$	$9\frac{1}{2}$	4.98	8	6
8	$13\frac{1}{2}$	0.400	$\frac{1}{2}$	$10\frac{5}{8}$	8	$\frac{3}{4}$	$\frac{7}{8}$	$11\frac{3}{4}$	6.15	11	8
10	16	0.470	$\frac{1}{2}$	$12\frac{3}{4}$	12	$\frac{7}{8}$	1	$14\frac{1}{4}$	4.26	14	10
12	19	0.555	$\frac{9}{16}$	15	12	$\frac{7}{8}$	1	17	5.09	23	12
14	21	0.566	$\frac{9}{16}$	$16\frac{1}{4}$	12	1	$1\frac{1}{8}$	$18\frac{3}{4}$	4.91	28	14
16	$23\frac{1}{2}$	0.630	$\frac{5}{8}$	$18\frac{1}{2}$	16	1	$1\frac{1}{8}$	$21\frac{1}{4}$	4.17	38	16
18	25	0.638	$\frac{11}{16}$	21	16	$1\frac{1}{8}$	$1\frac{1}{4}$	$22\frac{3}{4}$	3.97	42	18
20	$27\frac{1}{2}$	0.686	$\frac{11}{16}$	23	20	$1\frac{1}{8}$	$1\frac{1}{4}$	25	3.49	50	20
24	32	0.785	$\frac{13}{16}$	$27\frac{1}{4}$	20	$1\frac{1}{4}$	$1\frac{3}{8}$	$29\frac{1}{2}$	3.71	74	24
30	$38\frac{3}{4}$	0.902	$\frac{15}{16}$	$33\frac{3}{4}$	28	$1\frac{1}{4}$	$1\frac{3}{8}$	36	3.23	114	30
36	46	1.046	$1\frac{1}{16}$	$40\frac{1}{4}$	32	$1\frac{1}{2}$	$1\frac{5}{8}$	$42\frac{3}{4}$	2.80	174	36
42	53	1.192	$1\frac{3}{16}$	47	36	$1\frac{1}{2}$	$1\frac{5}{8}$	$49\frac{1}{2}$	2.88	251	42
48	$59\frac{1}{2}$	1.314	$1\frac{5}{16}$	$53\frac{1}{2}$	44	$1\frac{1}{2}$	$1\frac{5}{8}$	56	2.67	327	48
54	$66\frac{1}{4}$	1.445	$1\frac{7}{16}$	$59\frac{3}{4}$	44	$1\frac{3}{4}$	2	$62\frac{3}{4}$	2.56	415	54
60	73	1.564	$1\frac{9}{16}$	66	52	$1\frac{3}{4}$	2	$69\frac{1}{4}$	2.39	529	60
72	$86\frac{1}{2}$	1.823	$1\frac{13}{16}$	$78\frac{1}{2}$	60	$1\frac{3}{4}$	2	$82\frac{1}{2}$	2.47	830	72
84	$99\frac{3}{4}$	2.040	$2\frac{1}{16}$	$90\frac{1}{2}$	64	2	$2\frac{1}{4}$	$95\frac{1}{2}$	2.34	1179	84
96	$113\frac{1}{4}$	2.280	$2\frac{5}{16}$	103	68	$2\frac{1}{4}$	$2\frac{1}{2}$	$108\frac{1}{2}$	3.64	1639	96

72	86½	1.823	1 13/16	78½	60	1¾	2	82½	2.47	830	72
84	99¾	2.040	2 1/16	90½	64	2	2¼	95½	2.34	1179	84
96	113¼	2.280	2 5/16	103	68	2¼	2½	108½	3.64	1639	96

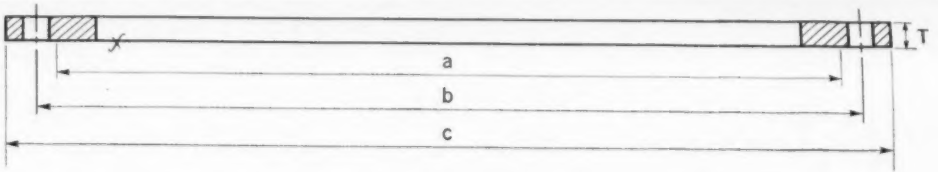


TABLE E

Ring Flanges for 150 Psi. Working Pressure
(Temperature Not to Exceed 200° F.)
Drilling Same as American Standard for Cast-Iron Pipe for 125 psi. Working Saturated Steam Pressure (B16a-1939)

1	2	3	4	5	6	7	8	9	10	11	12
Diameter of Pipe	Outside Diameter of Flange *c*	Thickness of Flange *T*		Outside Diameter of Gasket *e*	Number of Bolts	Diameter of Bolts	Diameter of Bolt Holes	Diameter of Bolt Circle *b*	Spacing of Bolts in Bolt Diameters	Approximate Net Weight of Flange—lb.	Diameter of Pipe
		Actual Design Value	Actual Thickness Used								
4	9	0.420	7/16	6 3/16	8	5/8	3/4	7½	4.71	6	4
5	10	0.454	7/16	7 5/16	8	3/4	7/8	8½	4.45	7	5
6	11	0.487	7/16	8½	8	3/4	7/8	9½	4.98	8	6
8	13½	0.566	9/16	10⅝	8	3/4	7/8	11¾	6.15	13	8
10	16	0.664	11/16	12¾	12	7/8	1	14¼	4.26	20	10
12	19	0.785	13/16	15	12	7/8	1	17	5.09	34	12
14	21	0.789	13/16	16¼	12	1	1 1/8	18¾	4.91	42	14
16	23½	0.887	7/8	18½	16	1	1 1/8	21¼	4.17	54	16
18	25	0.890	15/16	21	16	1 1/8	1¼	22¾	3.97	58	18
20	27½	0.958	1	23	20	1 1/8	1¼	25	3.49	72	20
24	32	1.096	1 1/8	27¼	20	1¼	1 3/8	29½	3.71	103	24
30	38¾	1.260	1¼	33⅝	28	1¼	1 3/8	36	3.23	153	30
36	46	1.465	1½	40¼	32	1½	1 5/8	42¾	2.80	245	36
42	53	1.657	1 11/16	47	36	1½	1 5/8	49½	2.88	357	42
48	59½	1.829	1 13/16	53½	44	1½	1 5/8	56	2.67	452	48
54	66¼	2.020	2 1/16	59¾	44	1¾	2	62¾	2.56	595	54
60	73	2.180	2 3/16	66	52	1¾	2	69¼	2.39	740	60
72	86½	2.530	2 9/16	78½	60	1¾	2	82½	2.47	1173	72
84	99¾	2.830	2 7/8	90½	64	2	2¼	95½	2.34	1643	84
96	113¼	3.150	3 3/16	103	68	2¼	2½	108½	3.64	2259	96

TABLE F

Comparison of Thickness and Weights of Flanges

Pipe Diameter	A.S.A. Standard Class 125 Cast-Iron Flanges		Steel Ring Flanges Drilling Same as A.S.A. B16a-1939*				Steel Ring Flanges With Proposed New Drilling Templates				Pipe Diameter
	1		2		3		4		5		
	125 Wsp.		75 Psi.		150 Psi.		75 Psi.		150 Psi.		
	Thk.	Wt.	Thk.	Wt.	Thk.	Wt.	Thk.	Wt.	Thk.	Wt.	
4	15/16	15	1/2	6	1/2	6	1/2	5	1/2	5	4
5			1/2	7	1/2	7					5
6	1	24	1/2	8	1/2	8	1/2	7	1/2	7	6
8	1 1/8	39	1/2	11	9/16	13	1/2	10	9/16	13	8
10	1 3/16	52	1/2	14	11/16	20	1/2	13	5/8	17	10
12	1 1/4	80	9/16	23	13/16	34	1/2	15	11/16	23	12
14	1 3/8	102	9/16	28	13/16	42	9/16	24	3/4	31	14
16	1 7/16	127	5/8	38	7/8	54	9/16	29	13/16	42	16
18	1 9/16	140	11/16	42	15/16	58	5/8	36	13/16	46	18
20	1 11/16	170	11/16	50	1	72	11/16	47	1	74	20
22							3/4	60	1	80	22
24	1 7/8	260	13/16	74	1 1/8	103	3/4	65	1 1/16	92	24
26							13/16	75	1 1/16	98	26
28							7/8	100	1 1/4	144	28
30	2 1/8	360	15/16	114	1 1/4	153	15/16	118	1 1/4	157	30
33							1	142	1 3/8	201	33
34											34
36	2 3/8	520	1 1/16	174	1 1/2	245	1 1/16	164	1 7/16	226	36
38											38
39							1 1/16	177	1 1/2	254	39
40											40
42	2 5/8	750	1 3/16	251	1 11/16	357	1 3/16	238	1 11/16	343	42
45							1 1/4	261	1 3/4	392	45
48	2 3/4	920	1 5/16	327	1 13/16	452	1 1/4	282	1 13/16	431	48
54	3	1150	1 7/16	415	2 1/16	595	1 3/8	364	1 7/8	492	54
60	3 1/4	1400	1 9/16	529	2 3/16	740	1 7/16	421	2	578	60
66							1 1/2	479	2 1/16	646	66
72	3 1/2	2040	1 13/16	830	2 9/16	1173	1 9/16	540	2 3/16	778	72
78							1 5/8	608	2 1/4	862	78
84	3 7/8	2840	2 1/16	1179	2 7/8	1643	1 11/16	675	2 5/16	943	84
90							1 3/4	783	2 3/8	1029	90
96	4 1/4	3820	2 5/16	1639	3 3/16	2259	1 3/4	865	2 7/16	1117	96
102							1 13/16	914	2 9/16	1303	102
108							1 7/8	996	2 5/8	1401	108
114							1 15/16	1087	2 5/8	1470	114
120							2	1172	2 11/16	1566	120

* American Standard Cast-Iron Pipe Flanges and Flanged Fittings, Class 125.

TABLE G

Comparison of Various Steel and Cast-Iron Flanges

Diameter of Pipe	Proposed New Flanges 150 Psi. Working Pressure New Drilling Templates Steel Flanges			Proposed New Flanges 150 Psi. Working Pressure 125 Psi. C.I. Drilling Steel Flanges			Proposed New Flanges 75 Psi. Working Pressure New Drilling Templates Steel Flanges		
	OD. of Flange	Bolt Circle Diam.	Thick. of Flange	OD. of Flange	Bolt Circle Diam.	Thick. of Flange	OD. of Flange	Bolt Circle Diam.	Thick. of Flange
4	8	6 5/8	1/2	9	7 1/2	1/2	8	6 5/8	1/2
5				10	8 1/2	1/2			
6	10 3/4	9 1/8	1/2	11	9 1/2	1/2	10 3/4	9 1/8	1/2
8	13 1/2	11 3/4	9/16	13 1/2	11 3/4	9/16	13	11 3/8	1/2
10	15 5/8	13 3/4	5/8	16	14 1/4	11/16	15 5/8	13 3/4	1/2
12	18	16	11/16	19	17	11/16	17 5/8	15 3/4	1/2
14	20	18	3/4	21	18 3/4	11/16	20	18	9/16
16	22 1/2	20 1/4	13/16	23 1/2	21 1/8	7/8	22 1/4	20	9/16
18	24 1/2	22 1/4	13/16	25	22 3/4	15/16	24 1/2	22 1/4	5/8
20	27 1/2	25	1	27 1/2	25	1	27	24 3/4	11/16
22	29 1/2	27	1				29 1/2	27	3/4
24	31 1/2	29	1 1/16	32	29 1/2	1 1/8	31 1/2	29	3/4
26	33 1/2	31	1 1/16				33 1/2	31	13/16
28	36 1/2	34	1 1/4				36 1/2	34	7/8
30	38 3/4	36	1 1/4	38 3/4	36	1 1/4	38 3/4	36	15/16
33	42 1/4	39 1/2	1 3/8				42 1/8	39 1/2	1
36	45 1/4	42 1/2	1 7/16	46	42 3/4	1 1/2	45 1/8	42 1/2	1 1/16
39	48 1/8	45 1/2	1 1/2				48 1/8	45 1/2	1 1/16
42	52 1/4	49 1/2	1 11/16	53	49 1/2	1 11/16	52 1/8	49 1/2	1 3/16
45	55 5/8	52 3/4	1 3/4				55 1/8	52 1/2	1 1/4
48	58 5/8	55 3/4	1 13/16	59 1/2	56	1 13/16	58 1/8	55 1/2	1 1/4
54	64 5/8	61 3/4	1 7/8	66 1/4	62 3/4	2 1/16	64 5/8	61 3/4	1 3/8
60	70 5/8	67 3/4	2	73	69 1/4	2 3/16	70 5/8	67 3/4	1 7/16
66	76 5/8	73 3/4	2 1/16				76 5/8	73 3/4	1 1/2
72	83 1/8	80	2 3/16	86 1/2	82 1/2	2 9/16	82 5/8	79 3/4	1 9/16
78	89 1/8	86	2 1/4				88 5/8	85 3/4	1 5/8
84	95 1/8	92	2 5/16	99 3/4	95 1/2	2 7/8	94 5/8	91 3/4	1 11/16
90	101 1/8	98	2 3/8				101 1/8	98	1 3/4
96	107 1/8	104	2 7/16	113 1/4	108 1/2	3 3/16	107 1/8	104	1 13/16
102	113 5/8	110 1/4	2 9/16				113 1/8	110	1 13/16
108	119 5/8	116 1/4	2 5/8				119 1/8	116	1 7/8
114	125 5/8	122 1/4	2 5/8				125 1/8	122	1 15/16
120	131 5/8	128 1/4	2 11/16				131 1/8	128	2

NOTE: 1. The A.S.A. flanges are based on 150 psi. at 500°F. and are rated at 230 psi. at 100°F.
2. The Am. Std. 125-lb. cast-iron flanges, the A.S.A. 150-lb. flanges are identical, excepting material.
3. The Am. Std. 125-lb. and the Am. Std. 25-lb. flanges have the same drilling templates.

TABLE G—*Continued*

Comparison of Various Steel and Cast-Iron Flanges—Continued

Diameter of Pipe	Proposed New Flanges 75 Psi. Working Pressure 125 Psi. CI. Drilling Steel Flanges			* Am. Std. CI. Pipe 125 Psi. Max. W.S.S.P. Standard Drilling Cast Iron Flanges			† Am. Std. CI. Pipe 25 Psi. Max. W.S.S.P. Standard Drilling Cast Iron Flanges			‡ Am. Stds. Assoc. 150 Psi. Flanges Standard Drilling Steel Flanges		
	OD. of Flange	Bolt Circle Diam.	Thick. of Flange	OD. of Flange	Bolt Circle Diam.	Thick. of Flange	OD. of Flange	Bolt Circle Diam.	Thick. of Flange	OD. of Flange	Bolt Circle Diam.	Thick. of Flange
4	9	7½	½	9	7½	15/16	9	7½	¾	9	7½	11/16
5	10	8½	½	10	8½	15/16	10	8½	¾	10	8½	11/16
6	11	9½	½	11	9½	1	11	9½	¾	11	9½	1
8	13½	11¾	½	13½	11¾	1⅛	13½	11¾	¾	13½	11¾	1⅛
10	16	14¼	½	16	14¼	1 3/16	16	14¼	⅞	16	14¼	1 3/16
12	19	17	9/16	19	17	1¼	19	17	1	19	17	1¼
14	21	18¾	9/16	21	18¾	1⅜	21	18¾	1⅛	21	18¾	1⅜
16	23½	21¼	⅝	23½	21¼	1 7/16	23½	21¼	1⅛	23½	21¼	1 7/16
18	25	22¾	11/16	25	22¾	1 9/16	25	22¾	1¼	25	22¾	1 9/16
20	27½	25	11/16	27½	25	1 11/16	27½	25	1¼	27½	25	1 11/16
22												
24	32	29½	13/16	32	29½	1⅞	32	29½	1⅜	32	29½	1⅞
26												
28												
30	38¾	36	15/16	38¾	36	2⅛	38¾	36	1½			
33												
36	46	42¾	1 1/16	46	42¾	2⅜	46	42¾	1⅝			
39												
42	53	49½	1 3/16	53	49½	2⅝	53	49½	1¾			
45												
48	59½	56	1 5/16	59½	56	2¾	59½	56	2			
54	66¼	62¾	1 7/16	66¼	62¾	3	66¼	62¾	2⅛			
60	73	69¼	1 9/16	73	69¼	3⅛	73	69¼	2¼			
66												
72	86½	82½	1 13/16	86½	82½	3½	86½	82½	2½			
78												
84	99¾	95½	2 1/16	99¾	95½	3⅞	99¾	95½	2¾			
90												
96	113¼	108½	2 5/16	113¼	108½	4¼	113¼	108½	3			
102												
108												
114												
120												

* Am. Std. Cast-Iron Pipe Flanges and Flanged Fittings Class 125 A.S.A. (B16a-1939).

† Am. Std. Cast-Iron Pipe Flanges and Flanged Fittings for Max. WSP of 25 Lb. A.S.A. (B16b2-1939).

‡ Steel Pipe Flanges and Flanged Fittings. A.S.A. (B16e-1939).

State Assistance in Engineering Design and Planning

By Adrian Langius

THE Michigan Public Improvement Fund Act is "an act to create a fund to assist local units of government to defray the cost of preparing certain surveys, plans and specifications; to provide for the disbursement of said fund; and to make an appropriation therefor."

The appropriated sum of $5,000,000 is "to cover one-half the cost of preparing surveys, plans and specifications from which the construction of public buildings, highways and streets, publicly-owned and operated facilities, utilities and services may be projected to be undertaken as postwar activities for the purpose of providing employment during the period of postwar industrial dislocation and resulting period of unemployment."

One million dollars of the fund is allocated for county road commissions.

One million dollars is allocated to cities, villages and townships for street and public improvement propects apportioned on the basis of the 1940 census of the local unit to the total state census. The per capita share is $0.16944. The public works official, to determine his approximate share, should multiply his 1940 census figure by $0.16944. Local units with a population of less than 1,182 receive the minimum established by the act—$200.

Three million dollars of the fund is earmarked for counties, cities, villages and school districts on the basis of the ratio of the population of the city or village to the total state population (1940 census) plus the total state school census. The per capita share is $0.4507053. County population is determined by subtracting the total for incorporated areas from the county total. City and village combined per capita share is $0.62.

Any project to be constructed with public funds, which requires the services of an architect, engineer or surveyor for the preparation of plans and specifications, is eligible. The local unit will be reimbursed for one-half the actual cost of the plans.

Plans and specifications may be prepared by employees of public works departments or by contract with consulting engineers, architects or surveyors. In either case, the work must be performed or supervised by a registered architect, engineer or surveyor. Expendable materials, office and equipment rental, etc., over and above the normal operating costs of the governmental unit, together with the payroll, can be figured in the local unit share.

Construction costs estimates and fees for plans will be determined by adding

A paper prepared by Adrian Langius and presented on April 27, 1944, at the Michigan Section Meeting, Jackson, Mich., by G. H. Gibson. Both Mr. Langius and Mr. Gibson are members of the State Planning Commission, Lansing, Mich.

to the 1940 local average costs, the percentage of increase in average construction cost indexes for 1943 over 1940, as determined by *Engineering News-Record*.

Because the Michigan Planning Commission began encouraging local units of government to start drafting plans about October 1, 1943, applications may be submitted for one-half the cost of preparing plans and specifications retroactive to this date, provided the plans were not completed prior to March 8, 1944.

All or part of the original allotment must be applied for prior to November 1, 1944. After this date all funds which have not been applied for and earmarked will become available to units needing additional funds, *provided* they have applied for all or part of the original grant prior to November 1, 1944. All funds not applied for by June 30, 1945 will revert to the general fund of the state.

There is no obligation connected with making an application and there will be a period following June 30, 1945, during which public works officials will be reimbursed for one-half the actual cost upon completing and submitting plans and specifications.

The procedure for applying for and obtaining state aid for plans is:

1. Write the Michigan Planning Commission for forms and manual.

2. Fill out triplicate forms for each project to be planned and return to the commission.

3. The plans will be referred to the state agency concerned for approval. For example, all highway and related projects will be referred to the Highway Department, water to the Health Department, sewage to the Stream Control Commission, schools to the Department of Public Instruction. This approval, as well as that of detailed plans and specifications later, is from a technical standpoint and is the same type of approval that has been necessary in the past. It is the policy of the commission that planning is a function of local units of government and should be done by local people familiar with the community needs.

4. Upon approval by the state agency concerned the application will be referred to the State Administrative Board which will process the form, earmark the amount of the grant for the unit and return one copy of the form to the applicant.

5. Payment will be made for one-half the actual cost of preparing plans when two sets of completed plans and specifications, construction, labor and material estimates are submitted and approved.

A certified copy of payroll and other costs and a state invoice voucher for the state's share must be submitted with the plans.

Public works officials are urged to file with the Michigan Planning Commission their complete public works programs, including projects already planned and prepared and those requiring state aid.

The complete programs will enable the Planning Commission: (1) to coordinate state and local programs and; (2) combined with unemployment studies now being conducted by the Michigan Unemployment Compensation Commission, to determine the adequacy of public works programs; (3) to act as a clearing house for information as to Michigan's postwar program; and (4) as the designated liason agency between the state and federal government, to present Michigan's needs for federal postwar financial aid, should that become necessary.

Postwar Planning

By John M. Hepler

IN the first place, it must be determined what is meant by postwar planning. This determination must be built up by sound thinking, good judgment and some guess work. There is little or no pattern to follow from the previous war or the depression period. There are only the final results of the WPA and PWA for a guide. In the past when the municipality, the county or the state knew what it wanted, prepared the necessary plans and accepted responsibility as sponsor, it got what it wanted. Those who had no plans and spent most of their time wondering how much they could get for nothing, usually got cemetery leaf raking, drainage ditch cleaning and maybe some old trolley line rails removed.

Today no one knows whether or not there will be any federal or state funds. So, as the starting point, why not forget the question of financing? We certainly cannot finance anything until we know what we want and get that want into a practical form—itemized, summarized and blueprinted.

We do know that the state has made funds available for planning. Sometime in the future—possibly at the immediate end of the war but possibly not until the present consumer demand is satisfied—there will be a period when labor and equipment must be employed, and manufacturing must be given a new source of orders. We must plan now for that period and the planning must follow one of two distinct patterns: the first, a plan that can be put into action quickly and that will employ many men for a relatively short period of time; the second, a plan that can be worked upon and developed over a longer period and which will require a longer period to consummate.

Should the war end suddenly—before the end of 1944 or before the alphabetical agencies can make up their minds whether industry shall be allowed to start retooling and preparing for conversion to consumer goods manufacture—the first plan will be badly needed. Should the war continue at a constantly diminishing tempo so that war production tapers off gradually and industry gradually converts into consumer production, the second plan will be needed somewhere in the future.

There is no phase of municipal activity that lends itself so easily to the development of a plan for either occasion than the water department. It has needs that have been known and talked about for the past 14 yr. Some of those needs were accomplished through WPA and PWA, but others have come to take their place. There

A paper presented on April 27, 1944, at the Michigan Section Meeting, Jackson, Mich., by John M. Hepler, Director, Bureau of Eng., Mich. Dept. of Health, Lansing, Mich.

is a bigger backlog of projects available now than there was at any time in the thirties. It behooves every one of us to get busy and find those projects and bring them to the attention of the city council and the local planning commission.

Analysis of needs can be divided into the two categories mentioned. Projects for quick utilization of labor involve additions to plant equipment, to distribution system and to operating improvements and might include:

(1) Additional pumping equipment.
(2) Additional chlorinating equipment.
(3) Rebuilding filters.
(4) Installation of gages, valves, meters, hydrants.
(5) Extension of mains.
(6) Connection of dead ends.
(7) Loop systems to bolster pressures.
(8) Cleaning or reconditioning elevated tanks, reservoirs, basins, mains.
(9) Replacing old services.

Projects for delayed construction or for improvement of supply include:

(1) Additional wells.
(2) Construction of filter plants, iron removal plants, softening or conditioning plants, elevated storage, and underground storage.
(3) Installment of auxiliary power.

Some of these items are dependent on additional equipment with little or no extra labor required. Others require considerable extra labor and not much material. Both types of projects are acceptable. Both types put labor to work, either in their manufacture or their installation.

From the water works official's viewpoint the major item of interest is to improve the utility and bring it up to current standards of efficiency, adequacy and dependability. Every change, addition or extension will contribute to the general planning picture of providing necessary work when it is needed. That is why water works men are urged to list everything needed in the supply, storage, pumping, treatment and distribution departments; build up projects to obtain those needs and submit them to their city officials and local planning commission.

Postwar Financing in Michigan

By Richard A. Sullivan

THE power of a municipality to go into the water business is derived from the state constitution itself, and under Article VIII, Sec. 24 of this constitution, the municipalities are given the power to issue revenue bonds *beyond* the general limit prescribed by law on bonded indebtedness, providing that the same are true revenue bonds secured only by the property and revenues of the water works. This same constitutional provision provides that, upon foreclosure, due to default upon the revenue bonds, the purchaser may operate the public utility and have a franchise for that purpose lasting not more than 20 yr.

It is under this Article VIII of the constitution that Act 94 of the Public Acts of 1933 was passed and held constitutional by the Michigan Supreme Court in the case of *Young* v. *City of Ann Arbor* (267 Mich. 241).

A bond secured only by the utility property and revenues is called a revenue bond, and a bond under which the full faith and credit of the city is pledged is called a general obligations bond.

The legislature has placed certain restrictions upon the issuance of general obligations bonds by municipalities. Under Sec. M.S.A. 5.1886, fourth-class cities can borrow not more than 5 per cent of their assessed valuation for building or extending their water works and such bonds can bear no more than 6 per cent interest, nor can they be sold for less than par; and in order to issue such bonds these fourth-class cities must first have the approval of two-thirds of the property owners. Under the heading of property owners come husbands and wives of the property owners. It took a constitutional amendment to permit the wives and husbands of property owners to have the privilege of voting on security issues.

This limitation placed upon fourth-class cities applies only to general obligation bonds, since, under Article VIII of the constitution, these same cities are permitted to issue revenue bonds. In general, the home rule cities have the same restrictions that apply to fourth-class cities, except that they are not limited by the 5 per cent valuation provision. The maximum issue of general obligation bonds for public utility purposes is controlled in each city by its own charter. Thus, if a home rule city reached its upper limit on general obligation bonds, all that need be done to issue additional general obligation bonds would be to amend its own charter. This obviates the necessity of going back to the legis-

A paper presented on April 27, 1944, at the Michigan Section Meeting, Jackson, Mich., by Richard A. Sullivan, Public Utility Consultant, Detroit, Mich.

lature. Act 94, which provides for the financing of sewage disposal systems, incinerators, etc., has specifically been held to be valid as conforming to the provisions of Article VIII, Sec. 24 of the constitution. Many engineers and executives have constructed plants under the provisions of this act. The city of Detroit, in building its $27,000,000 sewage disposal system, issued $5,022,000 of revenue bonds under the terms of Act 94, and thus Detroit's entire accounting procedure is controlled by the rules laid down in Act 94. In a recent case involving sewage disposal rates—*City of Detroit* v. *City of Highland Park*, Wayne County Circuit Court—it was necessary for Detroit to place interpretations upon certain sections of this statute. Sec. 21 of Act 94 is the section providing for minimum rates. The rates, according to this section, must be sufficient to provide: (1) bond and interest redemption fund; (2) administration and general expenses, including maintenance; (3) the building up of a reserve for depreciation; and (4) the building up of a reserve for improvements, betterments and extensions.

Literal Interpretation

Perhaps this section means what it says, but following the section literally means that the present rate payers should provide for: (1) payment of the plant which was built; (2) creating a reserve for replacing that plant; and (3) creating a fund with which to build another plant.

The author does not believe that it was the intent of the legislature to require any such interpretation to be placed upon this section, although it is believed that the rates must be sufficient not only to provide for the redemption of the bonds but also to create a complete depreciation reserve.

Depreciation Requirements

Some important lawyers and executives say that depreciation is not required under the decision of *Wolgamood* v. *Village of Constantine* (302 Mich. 384), which decision was handed down in 1942, but if any of you have plants which have bonds outstanding on them, issued under the provision of Act 94, you *must* provide for depreciation even though you are funding your debt. Here is what the Michigan Supreme Court said in the Constantine case:

> The question as to what amount a municipally-owned public utility should set aside for depreciation does not appear to have been determined in this State.
>
> A municipally-owned utility is built and operated, not for a corporate profit, but for the purpose of providing utility services at a reasonable cost to the citizens of the municipality, who are generally identical with the customers. For a municipally-owned light plant to charge rates which will, in addition to the necessary expenses of construction and operation, build up a reserve for depreciation equaling the replacement cost of the plant, is *to require the citizens and customers not only to pay for construction of their own utility but also to provide the capital for the construction of a new plant to serve future users.* The distinction between rates to be charged by a municipally-owned utility and a privately-owned utility is well expressed in Reed, *Municipal Management* (1941), p. 616, as follows:
>
> It is not necessary for a municipal utility, which is required by law to amortize its debt and which possesses the legal capacity to borrow, to accumulate also a reserve fund to replace its properties as they wear out. This is properly required of private utilities which expect to retain their bonded debt as a permanent part of their financial structure. *To require it of a municipal utility, however, is to ask the consumers to pay off the capital investment twice, once as a debt service and again in the establishment of a depreciation reserve.*

From what the court has said, it would appear that depreciation is not essential for municipal plants. However, the court went on to say that depreciation added to amortization of bonds was not essential—*only in the absence of statutory requirements.* Act 94 is a statute which requires both amortization of bonds and depreciation of plant. The act nowhere speaks of a retirement reserve but only of a depreciation reserve. There is a big difference, for under the doctrine of depreciation accounting the present ratepayer must pay off the bonds issued to construct the plant and also create a reserve out of which to build a new plant.

Maybe that is a good thing. Under a similar act covering municipally-owned utilities in Massachusetts, forty municipal gas and electric companies there have fared very well indeed.

Section 22 of the Act tells the utility what to do with the revenues collected from the rates prescribed in Sec. 21, but no other section in the entire act further defines the requirements of the rate-making section. It is in Sec. 22 that the requirement of five separate funds is stated. These five funds are as follows:

(1) Operation and maintenance fund.
(2) Bond and interest redemption fund.
(3) Depreciation fund.
(4) Contingent fund.
(5) Surplus fund.

It should be pointed out that the depreciation fund set forth in this section is not and cannot be the depreciation reserve created under Sec. 21. The depreciation fund created in Sec. 22 needs be sufficient to meet only those retirements which will occur during the ensuing two years, and is a cash fund. A true depreciation reserve is rarely, if ever, a cash fund. It is a reserve to provide for the ultimate retirement of property resulting from all causes. In a system of continuing life, the reserve is generally re-invested in plant.

Incidentally, depreciation should be predicated upon the original cost of the property. During the last decade many engineers have been led astray by the holding of the United States Supreme Court in the case of *United Railways* v. *West* (280 U.S. 234) where the Supreme Court laid down the rule that depreciation should be predicated upon fair value. This rule has been severely criticized by engineers and accountants but it was not until January 3, 1944 that the Supreme Court, in the case of *F.P.C.* v. *Hope Natural Gas Co.*, specifically overruled the West case and approved of "the propriety of basing annual depreciation on cost."

Reserve for Depreciation

That brings us back to Sec. 21 where the utility is required "to build up a reserve for depreciation." A reserve for depreciation, under the modern concept, should be a reserve predicated upon the service life of the plant. There is much controversy about this point but by far the weight of authorities is in accord with the statement that depreciation should be predicated upon the service life of the property. Thus, with respect to municipal utilities, if sinking fund obligations are not too great, they should endeavor to set aside each year a sufficiently large appropriation not only to care for the immediate retirements but also to create an adequate depreciation reserve which may be reinvested in plant, with a consequential diminution in the

amount of new money that will be required to be raised by the issuance of bonds.

Practically all gas and electric privately-owned utilities have greatly increased their appropriation to depreciation reserve from 1933 to date. For example, the annual charge to operating expense for depreciation by the Detroit Edison Co. in 1933 was $4,032,000, compared to $10,440,000 in 1943. During this same period the accrued reserve increased from $30,000,000 to $68,000,000. It is largely due to its depreciation policy that the Detroit Edison Co. has found it unnecessary to go into the open market and issue new securities in order to raise funds for property additions. It is interesting to note that the plant investment of the Detroit Edison Co. has increased from $288,000,000 in 1933 to $341,000,000 in 1943 without the issuance of a single bond or single share of stock. This should recommend one specific means of constructing additional plant facilities without the necessity of financing by bond issues. Many municipal water and sewage utilities are already setting aside about one-third of their total receipts as depreciation expense. They are to be commended for this practice, for the advantage of such procedure during wartime is obvious, and, whereever possible, their annual appropriation to depreciation should be pushed still higher. Now, more than ever, the customers are able to pay high water and sewage disposal rates. In some communities it might even be a good idea to increase industrial rates during wartime, particularly so where any increased costs are borne to the extent of 85.5 per cent by the federal government through the operation of the Excess Profits Tax Law.

Taxes to Local Communities

Perhaps this is a good point to mention to those of you who are city officials. Run a check on the amount of money paid by your industries in taxes to the local community and compare them to what they pay to the federal government. If some method of diverting some of the tax money flowing out of the state to the local municipal government can be found, much of the postwar financing problems will be licked. This is not unpatriotic. I venture to say that proportionately Michigan is contributing far more in tax dollars to this war effort than any other state in the country. Furthermore, your cities need the money to create postwar jobs during reconversion. There is about $360,000,000 in tax exempt government and foreign property which Detroit must service and yet which produces no tax revenues. This is an annual tax loss to the city of Detroit of about $12,000,000.

Federal Grants

As you are well aware, the federal government, in the economic depression of the thirties, in order to create jobs, passed out federal grants for public projects, which grants defrayed as much as 45 per cent of the total cost of construction. Today, during the war, the government, in many instances, is financing the complete cost of extensions to essential war industries; but after this war, in spite of much opinion to the contrary, the author does not believe that the federal government is going to continue its lavish spending, particularly if there is a change of administration for it appears that the majority of Congress is against the policy of federal grants for public projects.

Housing in Postwar Era

After this war, there undoubtedly will be a housing boom. Both public and private capital will be poured into new construction. To utility men new houses mean main extensions and new services, together with reinforcement of existing facilities, and it is well to bear in mind that even should the federal government be disposed to allocate funds for public projects, this is not the type of construction for which the federal government is likely to grant money. In the opinion of the author there will be no postwar grants for such unglamorous items as new service connections. Yet all water works men who are familiar with plant accounting know that when these little extensions and services are added up, they far exceed the cost of any single major project. For example, more than one-half of the total cost of the $120,000,000 plant investment of the Detroit water system is in distribution mains and services.

In order to provide for these postwar extensions, wartime earnings should be set aside to minimize the future bond issue requirements. Naturally, the lower the amount of the issue, whether it is a general obligation bond or a revenue bond, the lower will be the cost of borrowing the money. Stated conversely, the greater equity investment that the city is able to put into its own enterprise, the lower will be the interest rate on postwar bond issues.

In conclusion, attention should be called to the fact that bond issues are still tax exempt and with the bond market at its present level, good municipal bonds are selling at less than those of the United States Government. In fact, the city of Detroit can earn money by investing its general fund in government war bonds instead of calling in its own obligations.

WATER DIVISION REGIONAL ENGINEERS

The number of Regional Divisions in Water Division, Office of War Utilities, activities has been cut from 6 to 5.

The Regional Engineers and their areas are:

Region I, Bayard F. Snow; New England States, New York, New Jersey, Pennsylvania and Delaware.

Region II, George C. Sullivan; Maryland, District of Columbia, Virginia, North Carolina, West Virginia, Ohio and Kentucky.

Region III, Walter L. Picton; South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma and Texas.

Region IV, John R. Tanner; Michigan, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri, North and South Dakota, Nebraska and Kansas.

Region V, Gerald E. Arnold; Montana, Wyoming, Colorado, New Mexico and all states west thereof.

A Study of Water Rates in Michigan

By Louis E. Ayres

THERE are certain aspects of water rates wherein one finds a wide divergence in existing schedules. Among these are: (1) the range in unit charge as between that made to the average household and to the large industry; (2) the lack of specific charge, for the most part, for fire protection and public service; (3) the diversity in the application of "service" and "minimum" charges; (4) the complexity of many rate schedules as indicated by the number of "steps" superimposed on a number of meter charges; and (5) the wide range in charges for water sold to "suburban" areas.

To illustrate the variations of the above items, the author has reviewed the data on rate schedules of eighteen typical Michigan communities—six furnishing untreated water, seven with softening plants and five with filtration only on Great Lakes water. The communities furnishing untreated water have a range in population of from about 7,500 to 55,000; those with softening plants, and with but two exceptions filtration combined with softening, vary in population from about 15,000 to 170,000; and those with filtration plants only on Great Lakes water have a range in population of from about 15,000 to 1,800,000.

A paper presented on April 27, 1944, at the Michigan Section Meeting, Jackson, Mich., by Louis E. Ayres, Cons. Engr., Ann Arbor, Mich.

The comments herein are limited to these few rate schedules, without specific reference to any city. No adverse criticism of any schedule is intended; the examination has been too superficial to warrant passing judgment on the propriety of the charges made in any city.

In considering the small-to-average household, one may have in mind consumers that use from 1,200 to 2,000 cu.ft. per quarter, equivalent to 3,000 to 5,000 gal. per month, or 25 to 40 gpd. per capita for a family of four. Probably 50 per cent of the consumers of many water works are within this range. The other 50 per cent are divided between so-called "minimum users" on the one hand, and the larger domestic, commercial and industrial consumers on the other. The former may not be sold water on the basis of a unit charge but at a "minimum" charge or a "service" charge which should be sufficient to pay the carrying costs for a meter installation, reading, billing and collecting and a share of the overhead of administration.

For the purpose of examining the unit charge to the larger consumers, the rates per 100 cu.ft. per quarter have been computed for rates of 50,000, 100,000, 500,000, 1,000,000 cu.ft. per quarter and up to the largest consumers of 5,000,000 to 20,000,000 cu. ft. per quarter.

One may also think of the largest consumer in another way—of his size in relation to the total pumpage of a community. In this study the largest users vary from a consumption of about 25 to 365 cu.ft. per capita per quarter or from about 2 to 30 gpd. per capita; but for the most part the range is from 10 to 15 gpd. per capita or, say from 7 to 10 per cent of the total pumpage.

The charge for untreated water to the small household varies from 13 to 21.25 cents per 100 cu.ft., or the weighted average of water examined in six cities is about 14.5 cents. The charge in 12 cities furnishing treated water varies from 9.4 to 25.4 cents per 100 cu.ft., or the weighted average is nearly 19 cents, or about 4.5 cents higher than for untreated water.

The charge for water to the largest consumer varies from 1.4 to 6.5 cents per 100 cu.ft. for untreated water, with a weighted average of about 3.2 cents. The charge for treated water varies from about 5 to 11 cents, with a weighted average, omitting the effect of the Detroit area, of about 5.5 cents, or 2.3 cents higher than for untreated water.

The ratio between the unit charge for the use of 1,200 cu.ft. per quarter to the charge to the largest consumer varies, among these 18 cities, from 1.6 to 9.5. Considering the cities supplying untreated water the ratio is 2 to 9.5; but with the cities furnishing treated water it is only 1.6 to 4.5. Thus, there is a ratio of maximum to minimum rate of charge of nearly 5 to 1 with untreated supplies and about 3 to 1 with treated supplies.

The explanation, in part, for this larger ratio with untreated water is found in the rate structures of three communities of comparable size, all supplying well water. In one of these communities the wholesale rate is about 2.25 cents and in another 2.33 cents per 100 cu.ft., but in the third it is 6.5 cents; while the small household pays 15.7 cents in the first, 14.7 cents in the second and 12.7 cents in the third.

Obviously, the explanation of these variations is not to be found in any wide difference of the cost of production, distribution, etc., but in the theory applied by the rate structure. In the cities that sell as low as 2 cents per 100 cu.ft., the charge can not be greatly in excess of production costs only; while a wholesale charge of 6.5 cents for untreated water must include a liberal share in *all* costs plus, possibly, a profit.

It is interesting that in these three communities the largest consumers are in the towns with the lowest rates. Did the low rates produce the consumers, or did the consumers force the lower rates? Is it not more than likely that these very low wholesale rates are an inheritance from the past, when water companies operated on the theory that with a given going concern it is advantageous to add a large customer even if the added revenue is only slightly in excess of the added operating costs? The difficulty that such communities may soon face is that when they add a treatment process to their plant, they will be confronted with the alternative of a substantial increase in the rate to certain large customers or suffer a loss through the continued service to such customers. The sale of water to wholesale users at or near cost is, in effect, a subsidy. A new industry may be encouraged to locate in a community because of such a subsidy. Is the principle sound?

In another community of about the same size as those referred to above

(about 50,000 population), but with a treatment plant, there is a wholesale rate of 6 cents, with a charge to the small household of only 9.4 cents, or a ratio of 1.6.

In between these two extremes of 1.6 to 9.5 there are ratios of 2.0, 2.2., 2.3, 2.5, 2.7, 2.8, 3.0, 3.4, 3.7, 4.1, 4.2, 4.5, 5.3, 6.3 and 7.0. Obviously, there is not much consistency on this point in the schedules examined.

Steps in Rates

In these eighteen schedules the number of steps vary as follows:

No. of Schedules	*No. of Steps*
1	9
2	6
5	5
3	4
6	3
1	2

Why should any community need 9 steps in a rate, or even 5 or 6?

The purpose of steps is to effect a gradual transition in unit rate as the quantity purchased increases, although a similar result may be accomplished by fewer steps or a combination of fewer steps combined with service charges. Generally, the more steps in a rate schedule the more gradual will be the reduction in unit charge as consumption increases. As an illustration, with the community in the list with 9 steps, a user of 1,200 cu. ft. per quarter pays 7 times the wholesale rate; a user of 2,000 cu. ft. per quarter pays 6.8 times; of 4,000 pays 6.2 times; of 10,000 pays 5.2 times; of 50,000 pays 2.9 times the wholesale rate. At the other extreme in the list, a city with 3 steps charges a user of 1,200 cu.ft. per quarter only 1.6 times the wholesale rate instead of 7 times, or less than one-fifth as much as the town with 9 steps; and with the use of 50,000 cu. ft. per quarter only 1.1 times the wholesale rate, as compared with 2.9 times in the city with 9 steps. In a city with 6 steps the user of 50,000 cu.ft. per quarter is charged 4.2 times the rate for 3,000,000 cu.ft. per quarter. In the other towns this multiplier varies from 1.02 to about double the wholesale rate.

A user of 50,000 cu.ft. per quarter is a large user in about every city except a metropolitan area. It amounts to over 4,000 gpd. Can there be any justification for a unit charge to such a customer very much higher than to the very largest user?

Variation in Size of Step

There is also much variation in the size of the steps, particularly the lowest and the highest. The lowest is 5,000 gal. or 667 cu.ft. per quarter, one is at 1,000 cu.ft., two at 1,500 cu.ft., two at 2,000 cu.ft., and the balance range up to as high as 50,000 cu.ft. per quarter. The author has heretofore assumed that the first step in a rate might well be made at about that point where the average household begins to sprinkle, so that some encouragement would be given to the reasonable use of water for that purpose. Only about one-third of the schedules examined have steps, however, that have any significance to the average household. As to the highest step, or wholesale water, the range in these schedules is from a minimum of 1,000 to over 1,000,000 cu.ft. per quarter. With a minimum of 1,000 cu.ft. per quarter, practically all users are on the same basis. Water is sold like sugar or gasoline in the retail store. With 1,000,000 cu.ft. per quarter only a big user benefits, but in the town having this step the largest user buys about 13,000,000 cu.ft. per quarter and all over 1,000,000 is sold at 1.125 cents per 100 cu.ft.

Minimum and Service Charges

Minimum charges for a ⅝-in. meter vary from 80¢ to $2.70 per quarter. Frequently minimum charges are based on meter sizes.

One half of the towns have service charges based on meter sizes which are added to the unit water charge. The service charge for a ⅝-in. meter varies from 30¢ to $1.95 per quarter. Several of our larger cities have meter rates with 5 or 6 steps to which are added service charges for from 8 to 11 different meter sizes. The impression gained by inspection of these schedules is that a number are unduly complicated and must entail some unnecessary expense in their application; while on the other hand one or two schedules appear to have been unduly simplified.

Fire Protection and Public Benefit

Apparently only 5 of the 18 cities involved in this survey make any charge to the taxpayer for municipal fire protection and the public benefit from a water works, and the charges where made vary from 15 to 25 per cent of the total department revenue. One of these cities sets up the amount due on its books but does not make any cash collection. In another city the author was supplied with a tabulation of an "Estimate of Fire Protection and Water Consumed for Public Use," showing costs of about 13 per cent of the gross revenue, all of which are now absorbed by the water rates. Another city presented a carefully prepared computation upon which its fire protection charge is based, and in this case it is all collected from the taxpayers.

Water works men, generally, have long accepted the propriety of a charge against the taxpayers for fire protection and public benefit. But those concerned with city finances and taxation problems, who are confronted with the difficulties of raising sufficient funds to meet all of the demands of a municipal government under the tax limitation laws of Michigan, are not disposed to allow the public water department any funds for the use of fire hydrants, water to schools, public buildings, parks and similar services. These costs must, therefore, in most cities be distributed into the water rates. The method of making this distribution as between the various classes of users is a subject that might well receive attention.

Suburban Water Sales

The charge made for water sold outside the municipal boundaries varies in these schedules from 105 to 175 per cent of the charge within the city, although one community has a schedule that would carry a charge 5 times the municipal rate if a consumer existed to take the necessary quantity of water. At least one community does not permit the sale of water outside the corporate limits.

In considering the basis for sale of water to consumers and areas outside a city, there is no arbitrary rule or percentage that is properly applicable to all cities. Each case should be considered in relation to the local facts and conditions. Nor is the proper basis for determining rates within a city the same as the basis for outside rates. As the author has previously suggested, the rate structure within a city should provide sufficient revenue to pay (1) all debt requirements, (2) pay all operation and maintenance expense, and (3) create a sufficient reserve to meet all probable extensions except major plant improvements. In the consideration of such a rate struc-

ture such matters as interest on that part of the plant which is paid for and depreciation on the existing plant may be looked upon as more or less academic. However, it may sometimes be found that adequate allowances for extensions will require the collection of sums of money not far different from the usual allowances for interest and depreciation.

When one considers a rate for outside areas, however, it would seem reasonable to approach the problem on the usual assumptions for determining rates for a public utility. The water user beyond the city limits and beyond the reach of city taxes should pay a rate that includes interest and depreciation on the full investment in water plant devoted to his service, plus his share of operation and maintenance costs, plus a reasonable profit to the utility. Upon such a theory the charge for "outside"water will be higher than that within a city, principally in the interest allowance on that part of the water works which is free of debt and therefore the property of the taxpayers within the city.

Improper Interpretation

In connection with suburban water rates consideration should be given to certain assumed legal aspects which appear to have been given an improper interpretation.

It has recently come to the author's attention that the state law has been interpreted by some to *require* that cities and villages must sell water to outside areas at *double* rate. An engineer has lately advised a city to that effect, and the author is informed that such an interpretation of the law was given to the sewage plant operators at their last meeting, and that discussions have been held concerning the advisability of seeking either the Attorney General's opinion or an amended act from the Legislature.

The author has reviewed some of the statutes in this connection and, although not a lawyer, he can see no justification in existing laws for such an interpretation as above outlined. The principal acts bearing on this question are as follows:

Act 34, 1917, Sec. 1, which is the basis for the interpretation referred to and deals with the authority of municipal corporations only, says that such corporations "may contract for such sale with *cities* or *villages* having authority to provide a water supply for their inhabitants, but the price charged *shall not be less than nor more than double that* paid by consumers within their own territory."

This wording has been interpreted as meaning that the only legal rate was a "double" rate. Is that a fair interpretation? If the legislature had so intended the wording could have stated explicitly that the "price charged *shall be* double." No such interpretation is warranted in our judgment.

It is of interest to add that Sec. 3 of the same act provides that: "Where water is sold to purchasers other than cities and villages in such outside territory, such corporations shall exercise all the powers and have all the rights and remedies in connection with such water system in such outside territory, the sale and delivery of water therefrom, the *fixing of water rates* and the collection thereof." Obviously, from this wording there is no legal limitation on the sale of outside water to other than "other cities or villages."

It should also be added that Act 107, 1941, authorizes "township boards to contract with cities and villages for the furnishing of water to township water

supply districts . . . "under such terms and conditions as may be agreed upon."

Act 342, 1939, authorizes "counties to establish and provide connecting water . . . (within or) between cities, villages, townships . . . and to "establish just, equitable and uniform rates."

These examples are cited with the purpose of correcting any false impressions that may have prevailed, and with the suggestion that it might be wise to have a committee investigate the law and suggest any steps that might be desirable to effect a clarification.

Accounts and Annual Reports

Michigan has an account classification for water works used by the cities in varying degrees. Many cities, however, pay too little attention to their accounts and annual reports, and the account classification needs some revision.

An account classification, if it serves adequately, should effect such a segregation of both operating costs and fixed charges, in relation to operating revenue, as may be useful in fixing, checking and revising rates. For example, it should be relatively simple to determine, from a city's annual report, the total costs of production, distribution and consumer's costs, etc. But the necessary data to make such a determination are not now readily available. It would seem that the records of the water departments could be made more useful, without much added expense, in the keeping of books and records.

Rates are not unchangeable. Once determined by someone in the dark past, they should not remain forever inviolate. Yet that is the tendency. Some of the rate schedules examined date back over 20 yr.; and several are apparently based on rate theories in vogue more than 20 yr. ago.

Conclusions

The purpose of this paper has been to point out some of the wide variations and complexities in existing rate schedules, with the thought of calling your attention to a field of activity which appears to have been neglected and in connection with which a committee of the American Water Works Association might well make a contribution to the water works industry. There are certain fundamental principles in connection with rate structures, accounts and annual reports which might be reviewed by a committee and made available to the local membership of the A.W.W.A. Such a service could be helpful to communities if and when they face changes in water rate structures due to major improvements or financial readjustments.

Customer Meter Reading Calendar

IN February, 1943, as a means of conserving tires and gasoline, the Indianapolis Water Company, Indianapolis, Indiana, put into operation a customer mail-in "meter reading plan," which later fitted in nicely with meter reading problems such as manpower shortage and an increase in missed readings, because of entire families being engaged in war work.

In the beginning, 1800 meter reading calendars of three standard types of 5/8-in. meters were distributed in isolated districts of Indianapolis and suburbs, where the reading of meters demanded the use of a company car. Later, it was found advisable to send the calendars to customers where reading of the meter had been missed for several months in succession.

Originally the calendars were furnished to customers especially selected by the company, but in November of 1943 the company filed and obtained approval from the Public Service Commission of Indiana for a supplement to the company's rules and regulations. This supplement states, in part:

"Provisions will be made for customers who desire to read their meters monthly, to report such reading by mail on postcards provided by the Company."

As of June 1, 1944, out of a total of 86,911 active services, the company had outstanding 3,200 calendars.

Since the beginning of the war the company's meter readers have experienced difficulty and delay in getting into some of the larger defense plants in and about Indianapolis, to read meters. Recognizing the fact that many of these plants had personnel capable of reading water meters, in July 1943, the company began using a two-way postcard, in addition to the meter reading calendar. Co-operation from the list of firms participating in this program is practically 100 per cent, and at present approximately 450 readings per month are being made by this method.

A total of 11,640 meter readings were received by mail during the year, which is about 50 per cent return on the calendars in service last year. Of this percentage, inaccuracy and tardiness in receipt of the cards in the company's office reduced this figure another 5 per cent. The returns on the two-way postcards have been higher—about 95 per cent. Due to the increased number of calendars in service during 1944 and because customers are becoming more "read-you-own-meter" conscious, the company anticipated 20,000 mail-in readings to be received this year.

All residential meters are not read monthly. However, all commercial and industrial, as well as larger residential accounts are read each month. The average residential meter reading is on a quarterly basis, although not set up on a quarterly plan. On a quarterly basis the city would be divided

Meter Reading Calendar

Please read your meter on the ➔ of the month.

Mark and mail card promptly. Postage Paid

SEPTEMBER, 1944

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

NEXT YEAR'S lawn should be started now. The best time for seeding a lawn is in the Fall of the year rather than the Spring, according to experts. Clean the ground carefully, removing stones, twigs, and the like. Sow the seed evenly, rake it into the soil and then roll the lawn lightly. Take especial care with shaded portions and slopes.

Complete Instructions on Reading Meter on Back of Calendar

Please Mail This Card on the Date Noted Above or on Back of Calendar

Date of Reading_____

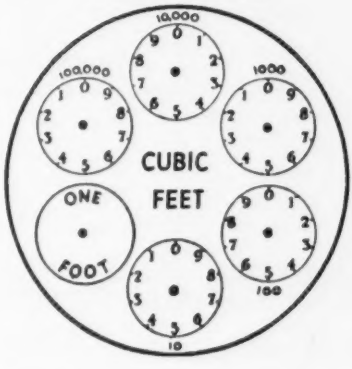
Reading_____

Address_____

Remarks_____

Signed_____ Acct. No.

Trident Meter Dial



into three districts and readings taken on each district every three months. The company reads as many of its residential meter books per day as its manpower permits and estimated bills are rendered on the balance. In this way, the company covers the entire city each month, obtaining readings on a probable one-third of its territory.

A check up as of May 31, 1944, on approximately 500 premises using meter reading calendars, reveals that customers are conscientious in marking the cards, and in no instance has it been found that customers have been sending in fake readings or running the meter dial back. The meter reading calendar might be classed as a "shock absorber" in cases where a customer does not always cooperate in sending in readings and where subsequent high bills due to leaks are rendered when readings are finally obtained.

The preparation of the calendars and the mailing of them, plus the two-way postcard mailings and entering all readings as they are received, is a sizable job, but the company has found the innovations in meter reading worth while.

We are indebted to H. S. Morse, Vice President and Manager, G. C. Staley, Chief Clerk and J. H. Pearcy, Chief Meter Reader, of the Indianapolis Water Co., Indianapolis, Ind., for the illustration of the meter reading calendar shown on page 1003, and for the facts regarding the unique meter reading program inaugurated by the Company.

Federal Transportation Tax

THE Revenue Act of 1943, effective June 1, 1944, continues in effect the exemption from payment of the transportation tax by states or their political subdivisions.

This means that water department employees may purchase tickets for any form of public transportation (where the tax applies; i.e. train, airplane, bus) without paying the 15 per cent federal tax, *if* the following conditions are met:

1. The travel must be recognized as official by the water department or city executive.

2. The official nature of the travel is, or will later be, evidenced by the payment (or reimbursement) of the amount paid for transportation.

3. The purchaser of the ticket or tickets presents to the agent of the common carrier a properly executed copy of Treasury Department form 731.

Copies of form 731 are obtainable from the various offices of the U.S. Internal Revenue Department. The completed form must be presented to the agent of the carrier when the ticket is purchased.

There has been a substantial amount of confusion concerning the tax exemption for employees of States and their political subdivisions. Staff personnel both of the Treasury Department as well as of the railroads, etc., have on some occasions advised that the exemption was no longer granted. This is erroneous as the copy of a letter from D. S. Bliss of the Internal Revenue Office states (*see* page 1006). If a common carrier's agent declines to sell a ticket or tickets to the holder of a properly executed copy of form 731, and insists upon the collection of the tax, (1) obtain the agent's official receipt for the (a) transportation and (b) tax; (2) record the serial number of the ticket or tickets bought; and (3) file a communication with the Internal Revenue Department requesting a directive to the carrier and/or its agent for the return of the amount of tax erroneously collected.

HARRY E. JORDAN,
Secretary

TRANSPORTATION AGENTS SHOULD NOT ACCEPT THIS CERTIFICATE UNLESS THE OFFICER OR EMPLOYEE PRESENTING IT SHOWS SATISFACTORY CREDENTIALS

Form 731
TREASURY DEPARTMENT
INTERNAL REVENUE SERVICE
(Revised Feb. 1944)

EXEMPTION CERTIFICATE

Tax on Transportation of Persons—Seats, Berths, or Staterooms

Place of issue of ticket ..... Date ....., 194..

Name of issuing carrier .....

Ticket Form No. ..... Ticket No. .....
(To be filled in by agent of carrier issuing ticket)

For ..... Via .....
(Transportation—seat, berth, or stateroom)

From ..... To .....

I CERTIFY that the charges for the service indicated above have been, or will be, paid by a State or Territory, or Political Subdivision thereof, or the District of Columbia, as indicated below, are incurred in the performance of my official duties, and are exempt from the tax imposed under section 3469 of the Internal Revenue Code, as amended.

....
(State etc., subdivision and service for account of which exemption is authorized) (Signature)

PENALTY FOR FRAUDULENT USE, $10,000 OR IMPRISONMENT, OR BOTH. .....
(Title)

NOTE.—A separate exemption certificate will be required for each ticket furnished or fare collected.

U. S. GOVERNMENT PRINTING OFFICE 16—83913-2

TREASURY DEPARTMENT
WASHINGTON 25

OFFICE OF
COMMISSIONER OF INTERNAL REVENUE

ADDRESS REPLY TO
COMMISSIONER OF INTERNAL REVENUE
AND REFER TO

MT:M:WDF

County of Westchester
Department of Finance
White Plains, New York

Attention: Mr. John T. Connell

Gentlemen:

Reference is made to your letter of June 23, 1944, relative to the tax on amounts paid for the transportation of persons imposed by section 3469 of the Internal Revenue Code, as amended. The question presented and the answer follow:

> "On June 9, 1944, one of our County officials, who was on official County business, presented Exemption Certificate, Form 731, Revised October 1941, to ticket agent, Pennsylvania Railroad, Washington, D. C., and was informed that tax exemption would not be allowed. Consequently, an amount of $5.69, Washington to New York, was paid which included a tax of 15%, or 74 cents.
>
> "Will you advise when section 3469 of the Internal Revenue Code was voided, and please send us a copy of such change."

Amounts paid for transportation by persons traveling on official business for the County of Westchester are not subject to the tax imposed by section 3469 of the Internal Revenue Code, as amended. That section of the Code has not been voided, and the termination of the general exemption from the taxes on the transportation of persons with respect to agencies and instrumentalities of the United States by section 307 of the Revenue Act of 1943, effective June 1, 1944, does not affect the exemption applicable to amounts paid by a State or political subdivision thereof for the transportation of persons.

The Association of American Railroads and the Air Transport Association of America have been notified that there has been no change in the exemptions applicable to amounts paid for transportation by a State or political subdivision thereof, and these associations have passed the information on to their members.

Very truly yours,

D S Bliss

D. S. Bliss
Deputy Commissioner

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

U. S. WATER SUPPLIES—GENERAL

California's Water Plan for Developing the Great Central Valley. *Twenty-four Major Storage Reservoirs—Irrigation for 10 Million Acres.* ANON. Western City. **19:** 9: 20 (Sept. '43). State water plan (Bul. 25, State Div. of Water Resources, '41) outstanding example of regional planning of water conservation control and utilization in nation. Designed to overcome unequal geographical distr. and unequal seasonal distr. of water supply in state. Plan for Sacramento and San Joaquin river basins provide for 24 major storage reservoirs with aggregate capac. nearly 18 mil. acre-ft.; 18 power plants capable of producing 7 billion kwh. annually; and use of underground storage reservoirs particularly in San Joaquin Valley. Large-capac. canals and pumping systems will transfer water from areas of potential surplus to those deficient, with exchanges on San Joaquin and Kern R., thus supplying ample supplemental water for all domestic, munic. and indus. uses in great Central Valley and San Francisco Bay Region for irrigating 10 mil. acres therein. Storm water storage in foothill reservoirs and release during dry season will: (1) control floods, (2) improve navigation on Sacramento R., (3) supply lands tributary to streams down which they pass, (4) control salinity in Sacramento-San Joaquin delta, (5) supply delta pool with surplus water which may be transferred to San Joaquin Valley and San Francisco Bay region, and (6) produce large new sources of elec. power. Key to this master plan is natural storage basin at confluence of Sacramento R. and San Joaquin R. with area approx. 40 by 25 mi. at sea level and criss-crossed by 500 mi. of waterways. Into these flows unused runoff from both river systems, avg. 31 mil. acre-ft. per yr. Such delta storage important in that when water reaches this point, all up-stream requirements met, whereas normally, surplus would waste into sea. Backbone of plan is Central Valley Project under constr. by U.S. Bur. of Reclamation.—*Ralph E. Noble.*

Schenectady's New Water Supply. ANON. Health News **21:** 12: 47 (Mar. 20, '44). New $400,000 well water supply rushed to completion in order to meet latest of no. of critical water shortages. Original water system installed in 1872 by private enterprise but purchased soon after by municipality. Supply taken from Mohawk R. and delivered without treatment. Typhoid fever not uncommon in city at that time and in 1895 new water source obtained from 3 dug wells in const. use ever since. Typhoid practically elimd. in community until '20 when river water backed into wells through old intake, resulting in outbreak of disease. Pipe then completely sealed off and chlorination app. installed for disinfection of water as precautionary measure during high levels of river. Water insufficient for several years, especially during drought, and more recently due to increased pop. and indus. usage. As temporary measure, emergency gravel-packed well installed in '40 to supplement dwindling supply. Well, located near site of 9 new wells on river flats few miles west of city, yielded about 3½ mgd. and alleviated critical shortage temporarily. As result of deficiency of rainfall during latter part of '43, became impossible for city to maint. storage in reser-

voir. Extensive campaign promoted for water conservation and emergency connection made to distr. system of Niskayuna Water Dist. from which ½ mgd. secured. Installation of pumping equip. at new source rushed to completion, wells and mains thoroughly disinfected and supply put into operation Jan. 18. Each of 9 new wells drilled into sand strata to depth of approx. 65′ and has inner and outer casings, 18″ and 24″ in diam., resp., annular space being packed with gravel. Fine screen attached to bottom of inner casing for purpose of excluding sand and other fine material. Each well provided with independent pumping equip. housed in bldg. constructed over well. Main operating and admin. bldg. located in center of group and contains control equip., lab., disinfection app. and 2 wells. Pumps discharge into grid of mains connected to main feeder to city. Provision made for treatment of water with chlorine and ammonia. Disinfection being carried on at outset merely as precautionary measure but to be used in future only during periods of high-water level in adjacent Mohawk R. Tests indicate this new development highly successful. Each well capable of producing unusually high yield of 3½ mgd. and supply should be adequate for many years. Old supply and pumping station being retained for emergency use.—*Ed.*

Santa Monica Uses Colorado River Water for Entire Supply. ANON. Western City **19:** 10: 38 (Oct. '43). Colorado R. water constituted practically entire supply of more than 60,000 Santa Monicans since June, '41, when Metropolitan Water Dist.'s $200,000,000 aqueduct put in operation. Present supply avgs. 100 ppm. hardness compared with 300 ppm. in former ground-water supply. Delivery under pressure sufficient to serve all 3 levels of distr. system by gravity flow alone. Higher cost of aqueduct water considerably offset by elimn. of pumping charges. Water rates increased 20% but laundries report increase offset by saving in soap with softer water.—*Ralph E. Noble.*

Water and the 1941 Drought in Georgia. M. T. THOMSON. Civ. Eng. **13:** 475 (Oct. '43). Producing steel for medium tank takes as much water as city of 5000 uses in day. Railroads carried about 500 billion ton-miles of freight last yr. Locomotives consumed more water than people of Georgia used in their houses. Army does not build camps unless adequate supply of water assured. Most military camps in Georgia located in coastal plain where water readily available in artesian beds. 2 major droughts occurred—in '25 and in '31. In terms of eng. facts, no figures engr. can put on his slide rule. As result of present stream-gaging program, hydr. engr. in Georgia has something tangible to work with. We often read that Georgia has abundance of water resources because its rainfall avgs. 50″ per yr. 12,000-sq.mi. area in northern Georgia has yield of less than 0.10 cfs. per sq.mi. and, for 8000 sq.mi. yield more than 15 cfs. per sq.mi.—*H. E. Babbitt.*

Efficiency of Topeka's Water Distribution. LLOYD B. SMITH. Kan. Govt. Jour. **29:** 4: 9 (Apr. '43). Improved accuracy in acctg. for all water distributed to households, institutions, indus. plants and city's own services first step in operating eff. Unacctd. for "leaks" cut into earnings. In '29, Topeka system acctd. for 57% of water pumped; in '42, over 82%. Such results obtained primarily through prompt repair of service connection leaks and effective meter use. Topeka's 21,054 water service connections 100% metered. Most potent factor in unacctd. for water loss reduction from 43% in '29 to 18% in '42, impressive meter maint. program, particularly testing routine. Although designed and constructed as precision instruments, water meters naturally subject to deteriorating influences lessening accuracy. Grit causes internal wear; water-borne chems. and minerals induce corrosion and scale formation; electrolysis may attack and threaten to disintegrate metal parts. Thus, eventually, meter may completely fail to register underflows of ¼ gpm. or less, or at least greatly under-register them. As approx. 11–16% of household water consumption at ¼ gpm. rate or less, accurate registration of *all* flow rates important. Ordinary toilet leak may run as high as ½ gpm. Calcg. amt. per hr., day or week gives interesting unregistered gallonage. Ordinary household meter in service gives close registration 5–10 yr. without removal. Essential for efficient water dept., however, to set up meter testing and reconditioning schedule to insure fair deg. of accuracy in measuring water distr. without prohibitive costs in labor, materials, new parts or instruments. Dept. also often uses calibrated tanks and rate-of-flow recording indicators. History of meter maint. and water rates relationship detailed, showing progressive lowering of latter.—*Ralph E. Noble.*

FOREIGN WATER SUPPLIES—GENERAL

Obstacles to Water Works Enterprise. THOMAS EDWIN HAWKSLEY. [Mr. Hawksley is Pres. of the Inst. of Water Engrs., a new Corporate Member of the Association.] Surveyor (Br.) **103:** 263 (June 2, '44). Service of water supply struggles against two fundamental handicaps: lack of ownership of water and lack of enthusiasm of those who have to pay for something essential to life itself. In old days mill owners strongest antagonists with whom it was rarely possible to agree on allocation of stream. Other antagonists are catchment boards, who have statutory duties to perform on slender resources, and fishery boards—most apprehensive bodies of all. Suggest that water undertakings approach fishery interests with large measure of sympathy instead of leaving them to dissipate their meager financial resources on contests in Parliament. Impounding of head waters destroys best spawning ground and suppresses natural freshets so fish will not run. Other less organized antagonists legion. Some claim right to preserve natural beauty. Others want to foul water they happen to be near. Mfr. pumps vast quants. from underground for process purposes and with him is owner of shallow well who dislikes even free piped supply as substitute. Coming of industries caused growth of villages where water power and minerals available. Towns small when it became necessary to procure water from surrounding country century ago. No provision made for supplying area beyond town. Towns have utilized resources within easy reach and when rural areas want supplies they have to buy water in bulk from towns with all statutory limitations on security of such bulk supplies. Reluctance to pay for service of water supply real factor in development of piped supplies and gives rise to attacks on companies because there are shares entitled to 10% dividend. But to look at this class of shares is misleading. If one takes whole of cash raised there is little to choose from between avg. rate paid for money and rate of interest paid for same sum on similar work.—*H. E. Babbitt.*

Water Supply on a National Basis. ANON. Surveyor (Br.) **103:** 101 (Mar. 3, '44). Planned control of country's water supplies may be considered in two aspects—one in which main basis is provided by river system, while in other consideration must be given to all defects, anomalies and clashings of interest which exist, and to quals. of water and stds. of purity. In discussion in House of Commons Levy stated: No local authority or private undertaking was capable of providing adequate water supply and drainage unless matter was dealt with by govt. under natl. water plan. Hutchinson referred to lack of adequate mchy. to insure full use of existing resources. Miss Lloyd George contended that conditions in rural Britain are such as to indicate imperative necessity for national scheme of water supplies. R. C. Morrison said confusion of policy had led to so great a fall in water levels in chalk that under London area it was 60 to 80′ lower than 20 yr. ago. First bill Minister of Health proposed to introduce would deal with water and sewerage. Existing arrangements, local and general, not regarded as satisfactory, and knowledge of river flow and underground water insufficient. Comprehensive scheme essentially different from that in govt.'s immediate prewar bill.—*H. E. Babbitt.*

Reorganization of the Water Industry. NORMAN G. ELLIOT. Wtr. & Wtr. Eng. (Br.) **47:** 118 (Mar. '44). Inst. of Water Engrs. and British Water Works Assn. have set up committees to report on subject and is certain that Ministry of Health and Ministry of Town and Country Planning chewing cud of problem in their own way. In small towns and rural dists. lamentable state of affairs often apparent. Root of trouble lies in small size of many undertakings. They cannot pay adequate staff; in fact, they hardly have staff. Small undertaking handicapped in another way for when new works required their cost appears totally disproportionate. Cure is to amalgamate smaller authorities into larger units. In a sense, water undertakings centrally controlled today by statute and by Ministry of Health, but important to realize difference between this type of control and that which aims at detailed admin. from center. Best size for water undertaking is largest, which can be completely controlled by one man. Pop. of about 300,000, where sufficiently dense, would be about ideal. Pop. of 50,000 might be considered minimum desirable. [American experience indicates that 50,000 pop. as a minimum for successful operation far too high.—*Editor.*] Local jealousy active and potent force and sufficient to

prevent most amalgamations. Some right of appeal necessary but unlikely that feeling would run very high over composition of boards especially if pill sweetened by financial relief from govt. Existing system of allocation of resources by Parliament clumsy, but it has worked. Avg. water works man in country dist. intelligent, with initiative and common sense; let him know what should be done and why, and he will not require repeated instructions. Objective is that every house in country shall be supplied with water. —*H. E. Babbitt.*

The Institution of Water Engineers. *Report of Committee on Postwar Planning.* Wtr. & Wtr. Eng. (Br.) **47:** 187 (May '44). *General Considerations:* Water must be obtained from sources at which it is and conveyed to centers of pop. requiring it. Water, unlike electricity, cannot be converted into any form more readily transmissible. Hence, National Water Grid not only impracticable but unnecessary. *Availability of Sources of Supply:* Existing and potential sources of supply ample for present pop. and also for any increase likely to occur. Greater knowledge of purif. of water renders it now feasible to utilize sources which few years ago would not have been practicable. *Protection of Supplies:* Supplies of statutory water works should forthwith be adequately protected by legislation as regards quant. and against poln. *Statutory Authority:* At present time various aspects of water supplies as whole controlled in England and Wales by Ministries of Health, Agriculture and Fisheries, War Transport, and Fuel and Power. We recommend permanent statutory authority, analogous in some respects to Electricity Comrs., should be set up. *Development of New Areas for Housing and Industry:* Sources of water supply can be prejudicially affected by development for bldg. purposes. Effects may be minimized if consideration given to reservation of more vulnerable areas. *Coordination of Existing Water Works:* We make no recommendation as to area which would constitute ideal water works. Best results will be obtained by water works themselves formulating own schemes. Whatever boundary problems arise thereon can only be solved satisfactorily by co-operation. *Rural Water Supplies:* Need for rural water supplies now recognized. Can be afforded in 3 ways: (a) from existing water works, (b) by parochial schemes and (c) by regional schemes. Parochial schemes often most economical of initiating supply to small village but generally difficult to supervise, often insufficient in drought years and incapable of expansion. *Inland Water Survey:* Duty should be placed on catchment boards to record and submit to central authority for publication flow of main rivers and tributaries within their jurisdiction. Geological surveys and memoirs should be brought up to date and rainfall maps completed. *Standard of Fittings:* Every effort should be made to return to good qual. fittings as early as possible after war. *Research:* Great need for research organization to cover all fields of water eng.—*H. E. Babbitt.*

The Control of Water Resources. *Second Report of Committee on Postwar Planning.* Wtr. & Wtr. Eng. (Br.) **47:** 209 (May '44). Committee divided main part of their work into: (a) water resources and (b) distr. of water supplies to consumer. Publishing 3 reports: (1) Underground Water (already published), (2) Control of Water Resources, and (3) Distribution of Water Supplies to Consumer (in preparation). In initial stage of development, i.e., early in 19th century, local resources generally sufficient. No longer adequate. Especially in its relation with water industry, Parliament has pursued policy of min. govt. interference. At present no govt. dept. or other body with specific duty of planning works of water supply. Sources of water supply that are relatively pure most valuable national resources. Less desirable sources will ultimately have to be utilized. Necessary that these should be conserved also. Committee driven to conclusion that water resources of this country should in future be regarded from national rather than local aspect. Water should be used in best interests of nation as a whole. Establishment of Central Water Authority recommended. Board of Public Water Supply, which would have general jurisdiction over water supply industry, should also be established. Parliamentary control must remain. Committee recommends establishment of dist. bodies for each region or dist. into which it is proposed that country be divided. Expenses incurred by Central Water Authority should fall on Exchequer. Those of Board of Public Water Supply should be borne by water works of country. System of control proposed for England should be extended for Scotland and Northern Ireland to cover whole United Kingdom.—*H. E. Babbitt.*

Water Supply. ANON. Engineering (Br.) **157:** 311 (Apr. 21, '44). Question of water supply has not caused much concern during present century until low rainfall of '32–'33 and prolonged drought of following year. These and similar factors, largely artificial in origin, combined to prepare way for campaign for constr. of "water grid," analogous to electricity-supply grid. Appreciated that immense postwar housing schemes would involve problems of water supply on increased scale. Hence arose govt. inquiry summarized in White Paper on "A National Water Policy." This consists of 2 sections—one outlining general policy and another dealing with aspects of problem in detail. Point emphasized in survey is that real problem not one of resources but of distr. Main proposals comprised in suggested national policy based on 3 principles. First, that there shall be adequate control of all services; second, that responsibility for domestic supplies shall rest with democratic bodies, and third, sectional interests shall be subordinated to national interests, but with right of appeal to responsible minister of Parliament. Now proposed that central planning of water policy shall be function of ministers who shall base plans "on information systematically collected and assessed, regarding water resources and needs." Central Advisory Water Committee for England and Wales, and corresponding body to be set up in Scotland, would be given powers and advise ministers. Work of Inland Water Survey to be "pressed with vigor." Present powers and duties of local authorities would be retained but Minister of Health would be given addnl. powers. Should need arise, one undertaking would be compelled to give bulk supply to another. Undertakings would be enabled to take water from rivers and to acquire land compulsorily. Broadly considered, proposed national policy appears to be sound enough in principle though obvious that to implement it on scale outlined may involve questions of expediency that may modify scheme in local detail.—*H. E. Babbitt.*

Postwar Water Supply. ANON. The Engineer (Br.) **177:** 328 (Apr. 28, '44). Even in those few cases where recommendations of Inst. of Water Engrs. not specifically mentioned in White Paper, clear that proposal to give health ministers statutory duty of promoting provision of adequate water supplies and conservation of water resources together with central planning of water policy gives them power to effect recommended improvements. White Paper proposals clearly put forward now because reorganization of water supply will become essential factor toward realization of other postwar plans. In view of govt.'s intention to give encouragement to research, it may be hoped that research in several fields of water eng. will not be neglected.—*H. E. Babbitt.*

Water Supply: Economic and Social Influences. DELWYN G. DAVIES. Surveyor (Br.) **103:** 247 (May 26, '44). Important difference between plans for reconstr. after this war and those of last war. Then devastation from bombing non-existent, life of civilian pop. hardly disturbed, and grave conditions of occupied countries small. Expansion or decline of water works dependent on many factors, such as postwar std. of living and location of industry and pop. In some areas foreign trade may be dominant factor; other areas may experience new industries; while few may be undisturbed. Intensity of demand depends principally on: adequacy of supply, std. of living cost, qual. and pressure, nature of industries, age and efficiency of water works, and size of community served. If supply plentiful, unmetered consumption high. Cost of distr. network major part of total cost of water supply. Larger towns, such as Glasgow and Edinburgh, with less than 1 mi. per 1000 persons, have more economical system than country areas with 8 mi. per 1000 persons. Age of network affects consumption, for the older the system the greater the loss. Pressure, however, more important factor. In home, high water pressure adds greatly to consumption by permitting high delivery rate. Extent of consumption by industries considerably greater than domestic demand. Modern tendency is toward more elaborate methods of indus. production involving widening variety of clean water demand. Beyond bare min. personal requirement of 5 gpd. (Imp.), domestic demand governed by improved and increasing variety of household equip., improvement in personal habits, and domestic gardens. One essential feature of high demand is that of hot water supply. Proposed rehousing of one-third of Britain's pop., in 4 million new homes, will require vast national increase in water supplies. Many reasons given for great disparity in per capita consumption from 15 to 70 gpd. (Imp). Restriction in use of water

falls into 2 categories—voluntary and compulsory. Former has wrought remarkable reductions. Extravagant consumption can be reduced by metering. Water needs of agriculture probably greater than domestic and indus. demands combined. Dairy farm with 50 head of cattle has potential water demand of 2600 gpd. (Imp.). Absence of proper supply perhaps more serious to farmer than to town dweller.—*H. E. Babbitt.*

Research in Water Engineering. C. A. BRADLEY. Surveyor (Br.) **103:** 195 (Apr. 28, '44). Need for organization to disseminate information bearing on water eng. and to maint. contact with work carried out abroad. Main sources through which new information of use of water engrs. made available listed under 5 headings: theoretical and scientific subjects; materials of use in water eng.; design and constr. of new eng. works; maint. and operation of water undertakings; and management of water undertakings. Two main difficulties are provision of finance and method of organization of research work under present constitution of water industry. Suggestions as to future developments made. Proposals placed in order of anticipated expense: (1) Formation of research board of leading water engrs. with representatives of mfrs. and existing research organizations. (2) Provision of research scholarships to finance students on water works problems. (3) Appointment of technical official with such staff as would be found necessary: (a) to organize research work, (b) to organize publication of such work, (c) to prepare and publish abstracts of all British and foreign articles dealing with water eng., (d) to have charge of library to be made available for water engrs., (e) to give lectures and organize refresher schools. (4) Formation of testing station to test new materials and processes. (5) Formation of research assn. with lab. for exptl. research.—*H. E. Babbitt.*

CANADIAN WATER SUPPLIES—GENERAL

An Analysis of Data on Canadian Water Works Systems. A. E. BERRY. Eng. Cont. Rec. **57:** 16: 42 (Apr. 19, '44). About 95% of urban pop. and 50% of total pop. supplied from public water systems, about 1300 of 1647 urban communities having water supplies, mostly publicly owned. Surface water supplies predominate. 12 slow sand filter plants, 47 pressure plants and 70 rapid sand plants. Few pressure type plants built in recent years and pop. so served only 225,000, compared with 3,500,000 served by gravity mech. plants. Avg. cost of latter type plant is $11.34 per capita, $68,000 per mil.gal. designed capacity, or $159.20 per sq.ft. sand area. Chlorination almost universally practised. In Ontario, over 80% of all water used for domestic purposes so treated. Water mains avg. 8.1′ per person served and avg. cost of 6″ main, predominant size, $2.21 per ft. Avg. no. of services per mi. of main is 111 and avg. no. of persons per service 4.2. In '41, avg. hydrant maint. cost for 75 municipalities $4.57 each. Fire protection charges usually based on no. of hydrants—in '40, such charges avgd. somewhat under $40 per year, but this includes no. of places where charges low and not in accord with services rendered. Fire protection charges avg. $307 per mi. of mains, 0.723¢ per in.-ft. of main, or 12% of total operating costs of water works systems. Avg. per capita value of water works systems is $47.84 and avg. per capita cost of supplying water $4.83, of which $1.97 is for debt charges —if debt-free systems excluded, $2.15. Water cost per 1000 gal. pumped in majority of cases between 8¢ and 15¢—in 34 largest municipalities avg. is 13.75¢, in 2 largest 11.7¢ and some as low as 3¢. Avg. cost for 5-room houses assessed at $2,000 is $16 per year for flat rate supplies and $14.45 for metered supplies.—*R. E. Thompson.*

Water Situation in Southern Ontario. A. F. COVENTRY. Civ. Eng. (Br.) **38:** 51 (Mar. '43). All not well with water supply of southern agric. Ontario. Recent investigations confirmed fears for stability of supply. Mayall's findings on water situation in King Township show township has had 200 mi. of watercourses. 100 yr. ago all carried permanent streams; now 80 to 85% becoming waterless. Originally, 80% of township covered with mixed forest. At present, not more than 11% wooded and half of that grazed. Douglas reported that all 15 townships of Grey County suffered from seasonal shortage of water. Underground reservoir in Durham County stands at lower level than in earlier days. Streams of Peel Plain region reveal conditions closely comparable to King Township. In area considered, 67% of streams

temporary and situation becomes worse on further anal. In lowland, 82% of streams fail. Agric. plain now unable to maint. permanent stream. All these assignable to same cause—removal of too much of original cover. Floods and droughts not only evil of unbalanced water system. Coupled with them is soil erosion. Sheet erosion most widespread form. Most streams of Ontario dirty after rain. Gullying may also be destructive in sandy and gravel soil, as can be seen along shore of Lake Erie. No significant diminution in annual rainfall. Now streams disappearing, largely in one annual spectacular splurge at time of spring floods. Conditions will almost certainly get worse as more cover removed from land and more land left open to attacks of wind and water. Reconstr. plans must be fully prepd. during war. Treatment given reconstr. will play large part in detg. future of province.—*H. E. Babbitt.*

Brantford (Ont.) Plans Addition of Fluorine to Water Supply. ANON. Eng. Cont. Rec. **57**: 16: 58 (Apr. 19, '44). Report of Board of Health to Brantford City Council recommending addn. of 1 ppm. F to city water supply reproduced. Report points out that F is 20th most common element but that it is unevenly distributed. Brantford's supply completely lacking in F. Where water contains 2 ppm. F or more, teeth stained. In Oakley, Idaho, water supply contained 6 ppm. and incidence of dental fluorosis was 100%. In '25, F-free supply substituted and survey 8 yr. later showed complete absence of dental fluorosis. Observers in various countries have noted that tooth decay less prevalent in dists. where dental fluorosis found. In England, Ainsworth found 12.9% decayed temporary teeth in areas of dental fluorosis and 43.3% in other dists. Dean has shown that there is little dental decay and only scattered cases of mottled enamel when drinking water contains 1 ppm. F. Chart included of 21 U.S. cities in which incidence of caries varies from 236 to 252 per 100 children examd. in group with water supplies contg. >1.5 ppm. F to 556–1037 in group with F contents under 0.5 ppm. Board points out that sporadic mild dental fluorosis may occur if 1 ppm. F added to water supply, but this is not considered important as dentists can remedy this condition. City council approved recommendation. Letter from Wm. L. Hutton, Medical Officer of Health, points out that prelim. surveys have indicated that children with life-long residence in Brantford have greater caries incidence than children with non-continuous residence record. Surveys will be repeated every year. —*R. E. Thompson.*

Edmonton's New Water Softening and Filtration Plant. ANON. Can. Engr.—Wtr. & Sew. **82**: 4: 17 (Apr. '44). Plans approved for new 15-mgd. plant on site adjoining present 10-mgd. filtration plant, which was recently modified to provide for softening. As in existing plant, softening will be effected by excess lime-soda-ash recarbonation process, condenser water at approx. 62°F. from nearby munic. steam-elec. generating plant being available to prevent freezing and to maint. water temp. favorable for effective softening at both plants. Citizens appreciation of soft water indicated by numerous complaints if hardness of delivered water exceeds normal range of 70–80 ppm. After addn. of lime, soda ash, alum, Cl and ammonium sulfate, water will flow through primary flocculator and clarifier and, after first-stage carbonation, through secondary flocculator and clarifier. Each flocculator and clarifier will be arranged to operate as unit in single concrete tank. After secondary recarbonation, water will flow through detention chambers to four 44 × 36′ filters, arranged for backwashing in half units. Detention periods will be: flocculators, 45 min.; clarifiers, 2 hr.; detention basins, 4 hr. Post-chlorination will also be employed.—*R. E. Thompson.*

Use of Activated Carbon. ANON. W.W. Inf. Exch.—Can. Sec. A.W.W.A. **5**: A: 1, 2, 3: 1(Feb. '44). Three tabulations of data regarding use of activated C in Canadian municipalities in '42. (1) C used, total cost and cost per mil.gal., water consumption, and kind of C employed. On basis of total water consumption in municipalities listed (data for water treated not available), avg. C used was 4.13 lb. per mil.gal., and avg. cost $0.41 per mil.gal. Total C used 76,115 lb. (2) Avg. dosage on basis of total output, max., min. and avg. dosages per mil.gal. water treated, no. of days employed, and percentage of total water treated with C. On basis of water treated, avg. dosage ranged from 0.28 to 80 lb. per mil.gal., and max. from 2.3 to 120. (3) Point of application, method of application, reason for use and results obtained. Chief reason for use, of course, to remove tastes and most municipalities reported successful results.—*R. E. Thompson.*

Activated Carbon in Canadian Water Treatment Practice. A. E. BERRY. Can. Engr.—Wtr. & Sew. **82:** 4: 24 (Apr. '44). Statistics regarding use of activated C in Canadian water treatment plants compared with those presented by Sigworth for U.S. plants. In '42, 76,115 lb. used at 23 Canadian plants, avg. dosage on basis of total water consumption in municipalities concerned (not water treated) was 4.13 lb. per mil.gal. (Imp.). Cost was 41¢ per mil.gal. consumed. Corresponding dosage for U.S. plants was 12.7 lb. per mil.gal. (Imp.). Max. dosages reported: Canada, 120 lb. per mil.gal. (Imp.); U.S., 456 lb. per mil.gal. (U.S.). Evidently, quite high dosages may be required at times, but such periods usually of short duration and over-all cost of treatment moderate. Practice in general is to apply C as early as feasible in purif. process. Avg. per capita water consumption in Canada in '42 was 109 gpd. (Imp.)—*R. E. Thompson.*

Weston (Ont.) Solves Taste Problems by Aeration. E. V. MANSER. Eng. Cont. Rec. **57:** 16: 48 (Apr. 19, '44). Supply, derived from deep wells, of excellent bacteriol. qual. but contains Fe, CO_2 and H_2S, latter imparting objectionable taste. Compressed air introduced under pressure of 8 psi. through pipes fitted with diffuser plates in basin 12′ deep removes taste. Two new wells drilled recently and it is planned to soften this new supply to zero hardness and thus reduce hardness of water delivered from 300 to 180 ppm. Pop. supplied nearly 9300, including sections of townships of North York and Etobicoke.—*R. E. Thompson.*

Montreal Has Unusual Larvae Problem. JOHN H. HARRINGTON. Eng. Cont. Rec. **57:** 16: 56 (Apr. 19, '44). Chironomus larvae from 5-mi. raw water aqueduct have gained access to filters and occasionally burrow through into effluent. Treatment of filters with NaOH at rate of 2 lb. per sq.ft. of sand surface afforded only temporary relief. Prechlorination at rate of about 5 ppm. would be required to control larvae. However, expts. have indicated that they perish in few hours in service mains under pressure. During '43, avg. of 0.74 ppm. Cl applied to effluent, residual after 10 min. contact being 0.20 ppm. Coliform contents per 100 ml.: raw water 750; filtered water 49; plant effluent 0.04; avg. of 26 remote services 0.24.—*R. E. Thompson.*

Pumping at Steep Rock. ANON. Can. Engr.—Wtr. & Sew. **82:** 1: 17 (Jan. '44). Description of pumping plant constructed to lower level of Steep Rock Lake to permit stripping overburden from valuable iron ore deposits. Part of lake to be unwatered has area of more than 4 sq.mi. and depth up to 300′, contg. estd. 121 billion gal. of water. 14 centrifugal pumps, each with capac. of 403 mgd. at 55′ head, mounted on 7 steel barges. 12 motors of induction type and 2, to be retained for permanent mine pumping plant, synchronous; all direct-connected and operating at 600 rpm. Each pair arranged for parallel operation at heads up to 100′ and series operation at heads up to 200′. Suctions are 30″, tapered to 36″, and suction lift is 6′8″. Discharge is through 24″ Naylor spiral-welded pipe, with Dresser couplings, to collecting basin from which water flows through tunnel into arm of lake separated by dams from area to be dewatered. More than 6 mo. continuous operation will be required to lower lake level sufficiently to commence stripping operations. Level now receding at rate of about 7″ daily. Pumping job alone will cost about $850,000, including purchase of pumps.—*R. E. Thompson.*

Prestressed Concrete Water Tank for Connaught Laboratories, University of Toronto. ANON. Can. Engr.—Wtr. & Sew. **82:** 2: 21 (Feb. '44). Water tank of prestressed design, completed in Dec. to supply lab. and farm connected therewith, has capac. of 200,000 gal. Structure, built at ground level, has tapered walls 5–7″ thick and surmounted by dome 2″ thick. Principle of preload system of design outlined.—*R. E. Thompson.*

Water Waste Survey for Quebec's Gravity Supply. E. SHAW COLE. Can. Engr.—Wtr. & Sew. **82:** 4: 22 (Apr. '44). Water delivered to city by gravity from Lake St. Charles, 700 acres in area and located 7 mi. north of city, through 3 transmission mains (40, 30 and 18″) discharging directly into 150 mi. of distr. mains or 30-mil.gal. storage reservoir. In '43, avg. consumption by 150,000 pop. was 35 mgd., equivalent to 230 gal. per capita. For no. of years, service to parts of distr. system curtailed by capac. of transmission mains, and war demands increased difficulty to extent that reservoir could not be filled. Accordingly, contract awarded for pitometer survey. Condition of transmission mains

found to be satisfactory. Distr. system divided into dists. and night flows detd., areas showing high night flows being examnd. for leaks with sound-intensifying instruments. When winter temporarily terminated work, 6.14 mgd. of leakage had been discovered and about 5 mgd. repaired. In all, 119 leaks located: 2 joints in 12" mains allowed 0.5 and 0.59 mgd., resp., to escape. Abandoned services found to be prolific source of leakage and several hydrants wasting in excess of 0.1 mgd. Pressure increased 5–30 psi. in various parts of system and reservoir can now be filled easily. Consumption decreased 3 mgd., other 2 mgd. probably representing increased consumption due to higher pressures and increased wastage from unrepaired leaks.—*R. E. Thompson.*

Treatment of Two Water Systems Under Joint Administration. E. H. VALENTINE. Can. Engr.—Wtr. & Sew. **82:** 4: 26 (Apr. '44). Since '33, munic. affairs of city of North Vancouver and dist. of North Vancouver administered by one commission, several depts., including water works, being operated by jointly employed supts. Water supplies derived from streams having source in vast hinterland to north. Arrangements made to comply with order-in-council of fed. govt. requiring chlorination as wartime measures described. City has pop. of about 11,500 and water supply drawn chiefly from Lynn Creek and from storage reservoir fed from same source. Two automatic visible vacuum chlorinators installed, attended only during night. Dist. largely residential and has pop. of about 8000. Water supply derived from several sources, two, Mosquito Creek and Kilmer Creek, being included in mandatory order concerning chlorination. Two manual chlorinators installed for treatment of former and 2 automatic machines for latter.—*R. E. Thompson.*

HYDRAULICS

Experimental Fluid Dynamics Applied to Engineering Practice. G. A. HANKINS. Engineering (Br.) **157:** 158, 177 (Feb. 25, Mar. 3, '44). In dealing with exptl. problems in fluid dynamics basic principles of dynamical similarity and dimensional anal. of paramount importance, since it is by application of these principles that expts. can be made on scale models and results transposed to full-scale prototypes. Main forces in fluid with which we are concerned: (1) inertia forces due to mass of fluid, (2) forces due to viscosity, (3) gravitational forces, and (4) compressibility or elasticity forces. If inertia forces only are concerned, requirement for dynamical similarity is that forces be proportional to mass times acceleration, but in large no. of cases which arise in practice both inertia forces and forces due to viscosity of fluid important. Dynamical similarity requires ratio of these two forces shall be const. or

$$\frac{\text{inertia force}}{\text{viscosity force}} = \frac{Vl}{\frac{\mu}{\rho}} \text{ (Reynolds number)} = \text{a constant}$$

where V = veloc.; l = linear dimension of system, μ = viscosity, and ρ = mass density. Another requirement of dynamical similarity is const. ratio between inertia forces and gravitational forces, or

$$\frac{\text{inertia force}}{\text{gravitational force}} = \frac{V^2}{\frac{lw}{\rho}} = \frac{V^2}{lg} = \text{a constant}$$

where w is weight density. Parameter $\frac{V}{\sqrt{lg}}$ is Froude number, used in models of flow of water over weirs and spillways. When velocs. in fluid motion exceed veloc. of sound in fluid dynamical similarity requires const. ratio between inertia forces and elasticity forces, or

$$\frac{\text{inertia force}}{\text{elasticity force}} = \frac{V^2}{\frac{E}{\rho}} = \frac{V^2}{a^2} = \text{a constant}$$

where E = modulus of elasticity and $\sqrt{\frac{E}{\rho}} = a$, veloc. of sound in fluid. Parameter $\frac{V}{a}$ usually known as Mach number. Should be same for model expt. and full-scale. Basic principle of dimensional anal. is that if we have relationship connecting certain dimensions, two sides of equation, when expressed in terms of length, time and mass, must give

identical powers of these 3 dimensions. Thus, in flow of fluid through long, uniform, horizontal pipe pressure gradient can be written

$$\frac{\partial P}{\partial l} = \phi(d^w V^x \rho^y \mu^z) \qquad (1)$$

P = pressure, d = pipe diam., ϕ = unknown function of quants. inside bracket. Dimensionally two sides of Eq. (1) must agree, hence

$$\frac{\frac{\partial P}{\partial l}}{\frac{\rho V^2}{2d}} = \phi_1\left(\frac{Vd\rho}{\mu}\right) \qquad (2)$$

$\frac{Vd\rho}{\mu}$ is Reynolds number for pipe flow. Important application of principles is detg. by model expts. of forces acting on body moving in straight line through fluid at const. speed. This can be expressed by

$$\frac{D}{\frac{1}{2}\rho V^2} = \phi\left(\text{shape}, \frac{Vl}{\frac{\mu}{\rho}}, \frac{V^2}{\frac{lw}{\rho}}, \frac{V^2}{\frac{E}{\rho}}\right) = \phi(\text{shape}, R, F, M) \qquad (3)$$

where D is resistance directly opposing motion, R = Reynolds number, F = Froude number, M = Mach number, and $D \div \frac{1}{2}\rho V^2$ is non-dimensional resistance coef. As result of expts. carried out by Tower nearly 60 yr. ago and subsequent interpretation of his results in light of hydrodynamic theory by Reynolds, engrs. have known for many years way in which oil film in lubricated bearing able to support imposed loads. If f = coef. friction of bearing, apparent that variables likely to be important are size, which may be represented by diam. D; speed of rotation N; load per unit projected area P; and viscosity of oil Z. Hence, $f = \phi(D, N, P, Z)$. Correct dimensional equation becomes

$$f = \phi_1\left(\frac{ZN}{P}\right) \qquad (4)$$

in which $ZN \div P$ is non-dimensional parameter. Uniform laminar flow in horizontal pipe provides one case in which resistance to flow can be detd. directly by equating pressure drop per unit length to viscous shear forces across pipe and assuming zero veloc. at pipe wall. Result is usually known as Hagen-Poiseuille law,

$$\frac{\partial P}{\partial l} = \frac{32\mu V}{d^2}$$

Law can be expressed in usual eng. form

$$\frac{\partial P}{\partial l} = \frac{\rho V^2}{2d}\left(\frac{64\mu}{\rho V d}\right) = \frac{\rho V^2}{2d}\frac{64}{R} \qquad (7)$$

from which it will be noted that friction coef. λ is equal to $64 \div R$. Prandtl has been able to show that, for smooth pipe, friction coef. can be expressed:

$$\frac{1}{\sqrt{\lambda}} = 2 \log (R\sqrt{\lambda} - 0.8) \qquad (8)$$

Von Karman has shown, in addn., that when frictional coef. independent of Reynolds number, exptl. results obtained on pipes artificially roughened by uniform sand grains of various grades represented by

$$\frac{1}{\sqrt{\lambda}} = 2 \log 7.4 \frac{r}{k} \qquad (9)$$

in which r is radius of pipe and k is height of sand grains. In detg. whether pipe must be considered smooth or rough, effective thickness of viscous wall layer is of interest. An approx. idea is indicated by

$$\text{thickness of viscous layer} = \frac{33d}{R\sqrt{\lambda}} \qquad (10)$$

It cannot be said that modern ideas on pipe flow resistance have reached stage in which they are generally applied in eng. design. Exptl. and theoretical work which has provided rational understanding of effect of surface roughness in pipe flow has had important application in aircraft design, and in design of buildings and structures where necessary to make provision for winds. In water flow between boundaries and with free surface, controlling forces are inertia, gravity and viscosity. Complete dynamical similarity requires same Froude and Reynolds numbers in model and prototype, in addn. to geometrical similarity. This is not practicable when water is used in both systems and many water-flow models operated on const. Froude-number basis, care being taken that velocs. in model system sufficiently high to produce fully turbulent flow. *Editorial discussion Ibid.* **158:** 171 (Mar. 3, '44).

One of most noteworthy features, implicit in scope of Dr. Hankins's paper, is great range of eng. activity in which fluid dynamics plays important part. Same lines of thought as govern application of results obtained from tests of ship models serve also for studying resistance to flow in pipes and channels, air resistance of ships upper works, or wind forces on a structure, or correlating behavior of lubricated journal bearings. Much has been discovered regarding quant. influences of roughness of surfaces by which flowing fluids bounded. Increased speeds of flight also among factors instrumental in bringing roughness effects into foreground of scientific consideration. Since behavior of fluids in motion so intimately bound up with their phys. properties, engrs. can with advantage make themselves better acquainted with liquids and gases with which they have to deal.—*H. E. Babbitt.*

Discharge of Pipes Flowing Partly Full. CARL ROHWER. Civ. Eng. **13:** 488 (Oct. '43). Discharge of pipes flowing partly full does not follow smooth variation in relation to depth. Pronounced break in discharge curve for depths greater than half diam. Flow then variable and depends on conditions nature of which not definitely detd. Discharge generally increased at much slower rate after depth exceeded about half diam. of pipe. When air admitted into pipe, discharge increases much faster than prolongation of straight-line portion of logarithmic plot would indicate, in spite of fact that rate of increase of cross-section of water in pipe becoming slower at these depths. General formula for discharge at depths less than half can readily be detd. It becomes: $Q = 790D^{0.62}H^{1.82}$ in which D = diam. of pipe in in., and H = depth in ft. at outlet. High deg. of accuracy cannot be expected from this method because errors of from 0.01 to 0.02′ possible in measuring depth.—*H. E. Babbitt.*

Removal of Air From Pipelines by Flowing Water. A. A. KALINSKE & PERCY H. BLISS. Civ. Eng. **13:** 480 (Oct. '43). When air pocket formed at summit of pipeline or beyond partly open gate valve, conduit flows only partly full and at end of pocket hydr. jump usually occurs. First phase of investigation concerned with ability of hydr. jump to entrain air. Agitation present in hydr. jump caused water to entrain air and mix it with flowing water. Beyond jump, except for air bubbles, pipe flowed full, and rate at which air eventually removed from pipe depended on ability of water flowing in pipe beyond jump to carry air bubbles along. Except for higher water flows jump pumped air into water at higher rate than flow beyond jump could handle. Excess air then blew periodically through jump. Anals. indicated that ratio of volumetric rate of air removal, Q_a, to water discharge Q_w, i.e., Q_a/Q_w, should be related to pipe slope, S, and a dimensionless quant. defined as Q_w^2/gD^5 where D is pipe diam. For lower discharges, air removal controlled by flow characteristics beyond jump, described by value of Q_w^2/gD^5. At higher discharges air removal controlled by hydr. jump since water flow beyond jump capable of carrying all air entrained by jump and more if available. When this occurred, found that Q_a/Q_w became function of Froude no. of approaching flow, since this no. characterizes ability of jump to entrain air. Froude no. defined as V_1^2/gh_1 where V_1 is veloc. approaching jump and h_1 is mean effective depth (water area divided by surface width). To start air bubble movement down sloping pipe, water flow needs be such that hydr. gradient very much less than pipe slope.—*H. E. Babbitt.*

Flow of Water Through Pipes and Open Channels. J. ALLEN. Surveyor (Br.) **102:** 199 (May 7, '43). Author discusses Nikuradse's results which indicate that, with laminar flow, roughness has no appreciable effect. Friction coef., f, tends to become const. at high Reynold's numbers. Colebrooke and White exptd. with 5 grades of surfaces. Author discusses 4 cases mathematically, presenting graphs for f plotted against Reynolds number (**R**) and log **R**; calcs. value of "square law f" corresponding to pipe uniformly covered with grains of given size; and quotes Colebrooke's observation that "attempt to express mathematically transition function for uniform sand roughness difficult." Author found his open-channel tests agreed closely with Bazin's law of variation of C with m, and presents comparison in table. Detailed anal. of Bazin and Manning formulas leads to conclusion that over wide range of conditions, law connecting Chezy's C with hydr. mean depth essentially of same nature as that which applies to rough cylindrical pipes.—*H. E. Babbitt.*

Profile Curves for Open-Channel Flow. DWIGHT F. GUNDER. Proc. A.S.C.E. **68:** 535, 1247, 1413, 1646 (Apr., Sept., Oct., Nov. '42) (*Abstracted*, Jour. A.W.W.A. **35:** 368 ('43)). *Author's Closure. Ibid.* **69:** 297 (Feb. '43). Acknowledgment of error in paper: Point of inflection for Bazin and Ganguillet-Kutter relations by straightforward, but extremely tedious, method of detg. point of inflection located by finding d^2y/dx^2 and solving this equation by approximation. In so doing serious error of computation committed. Second of conclusions should be written: (2) Use of differential equation of gradually varied flow at depths below both normal and critical depths should be made with reservations until more exptl. work done in this region of high-veloc. flow. Seems that further refinement in anal. should await addnl. exptl. data relative to various roughness factors and to profile curves themselves.—*H. E. Babbitt.*

Flow Characteristics of Rectangular Open-Channel Junctions. EDWARD H. TAYLOR. Proc. A.S.C.E. **68:** 1521 (Nov. '42). (*Abstracted*, Jour. A.W.W.A. **35:** 367 ('43).) *Discussion. Ibid.* **69:** 905 (June '43). Some of author's hypotheses not confirmed by expts. Plan of attack may require some modification. Necessary to assume y_3 and v_3 below junction of converging streams, establishing relation: $E_3 = y_3 + Hv_3$ in which E is total energy in part of stream indicated by subscript. Proposed method of attack may not be solution, but accts. more nearly for forces acting on streams. *Ibid.* **69:** 1154 (Sept. '43). G. H. HICKOX: Similar problem exists in pipe flow where several attempts made to predict discharge through orifices of irrigation sprinkler systems. Author's derivation of Eq. 3 from Eq. 1 of somewhat doubtful validity. At junction, flow not parallel to wall, but curved. This curvature of flow will modify assumptions. Assumptions regarding pressure might well have been verified experimentally. J. C. STEVENS: 17 yr. ago writer's short article assumed that pressure in each intersecting conduit would merge into common value at intersection. Momentum and energy relations based on mean velocs. Formula followed purporting to give theoretical energy losses when n pipes of varying sizes join at common junction at varying angles from which water flowed away in main. These formulas give approx. result and illustrate danger of simplifying assumptions if accuracy important. Taylor assume that depth in branch remained const. to wall main and was also equal to depth in mai above junction. Both incorrect. Flow i open-channel intersections and in intersectin pipes contain too many complexities unti more can be learned about how 2 stream mingle. C. J. POSEY: Should be emphasize that data and conclusions of this paper are fo flow deeper than critical throughout. Dat presented by author justify assumption tha depths in intersecting channels substantially same, with division, in case of dividing flow depending chiefly upon backwater character istics of 2 branch channels.—*H. E. Babbitt.*

Viscosity and Surface Tension Effects on V-Notch Weir Coefficients. ARNO T. LENZ Proc. A.S.C.E. **68:** 351 (Mar. '42). (*Abstracted*, Jour. A.W.W.A. **34:** 1473 ('42).) *Discussion. Ibid.* **69:** 163 (Jan. '43). G. H. HICKOX: In past, effects of viscosity and surface tension almost totally neglected. Use of V-notch weirs as measuring devices need not be confined solely to fluids of low viscosity such as water or lubricating oils. Effects of viscosity and surface tension on V-notch weirs paralleled more or less closely by effects on small ogee weirs. Comparison of measured discharges over eastern dam with model tests showed prototype coefs. smaller than those of model. Seems likely that neglected effects of viscosity and surface tension in small models would be found to be responsible.—*H. E. Babbitt.*

Submergence Effect on Sharp-Crested Weirs. JOHN K. VENNARD & ROY F. WESTON. Eng. News-Rec. **130:** 814 (June 3, '43). Principles of similarity used in anal. of tests of Francis, Fteley-Stearns, Bazin, Cox and Cone. Shown that all available data approach mini curve which characterizes effect of submergence on sharp-crested suppressed, contracted and Cipoletti weirs for large values of P/H_1 where P height of weir and H_1 upstream head above weir crest. Reliability and wide application of such curve obvious from numerous and varied tests from which prepd. Use to avoid lengthy weir formulas should prove convenient.—*R. E. Thompson.*